

2016 Water & Sewer Master Plans



City of Wichita, Kansas

Water Master Plan Burns & McDonnell Project No. 90341

July 2017

2016 Water & Sewer Master Plans

prepared for

City of Wichita, Kansas

Water Master Plan
Burns & McDonnell Project No. 90341

July 2017

prepared by

Burns & McDonnell Engineering Company, Inc. Kansas City, Missouri

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July 17, 2017

Ms. Deb Ary Utilities Engineer The City of Wichita, Department of Public Works & Utilities 455 N Main Wichita, Kansas 67202

Re: FINAL Documents

Burns & McDonnell Project No. 90341 – Water Master Plan Burns & McDonnell Project No. 90342 – Sanitary Sewer Master Plan

Dear Ms. Ary:

In accordance with the Water and Sewer Master Plans Executed Agreement, dated March 15, 2016, Burns & McDonnell is respectfully transmitting three (3) comprehensive hard copies and one (1) electronic (.pdf) copy of the FINAL Master Plan Documents, consisting of the following components:

- Comprehensive Executive Summary (Water and Sanitary Sewer)
- Water Master Plan
- Water Master Plan Appendices
- Sanitary Sewer Master Plan Collection System
- Sanitary Sewer Master Plan Collection System Appendix M
- Sanitary Sewer Master Plan Facilities

For clarity, the hydraulic models associated with each master plan have been delivered to City staff which includes the raw water system model, Hess reservoir system model, water distribution system model, and the collection system model.

Over the last 18 months, Burns & McDonnell assisted the City of Wichita's Public Works & Utilities Department in developing this Integrated Water and Wastewater Master Plan to prepare for projected changes in Wichita's population, problems caused by aging infrastructure, and treatment challenges posed by growth and/or stricter regulatory nutrient removal requirements anticipated through the year 2045.

In collaboration with the City, Burns & McDonnell developed Capital Improvements Plans (CIPs) for performance/hydraulic, growth related, redundancy/reliability, fire flow, and regulatory-driven improvements for the raw water, water treatment, and distribution systems, and at all five wastewater treatment plants, pump/lift stations, force mains, conveyance, collection systems. If implemented, these CIPs will help mitigate risks of overtaxing the City's water and wastewater infrastructure based on the water demand projections, and corresponding sanitary sewer loadings, evaluated in each planning period.



Ms. Deb Ary The City of Wichita, Department of Public Works & Utilities July 17, 2017 Page 2

The main project components, as summarized in the FINAL Master Plan document, include water and sewer system master planning, hydraulic modeling, water and wastewater treatment facilities evaluations, and development of the capital improvements planning for the entire water and sanitary sewer service area.

The treatment scenarios and related CIPs developed for the water and sanitary systems are presented in detail in the enclosed comprehensive Master Plan document. Nearly \$1B of combined improvements are set forth in the Water and Sanitary Sewer Master Plans. Through the use of the City's CIP program, the scheduled improvements can be completed in a manner that is affordable to the City's rate payers, while addressing performance, growth, and regulatory-driven concerns.

We sincerely appreciate the Public Works & Utilities Department, Ms. Ary, and her dedicated staff for the opportunity to complete this important project for the City of Wichita. Should you have any questions regarding the FINAL Master Plan document, please do not hesitate to reach out to us.

Sincerely,

Ryan Scott, PE

Project Manager, Water Master Plan

Kerrie Greenfelder, PE, BCEE, ENV SP

Project Manager, Sanitary Sewer Master Plan

KLG/cac

INDEX AND CERTIFICATION

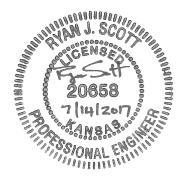
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Certification

I hereby certify, as a Professional Engineer in the state of Kansas, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the City of Wichita, Kansas or others without specific verification or adaptation by the Engineer.



Ryan J. Scott, P.E., KS No. 20658

Date: 07 14 2017

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LIST OF ABBREVIATIONS

<u>Abbreviation</u> <u>Term/Phrase/Name</u>

μg microgram

AFY acre-feet per year

AMWA American Metropolitan Water Agencies

ARV Air Vacuum Valve

ASR Aquifer Storage and Recovery

AWWA American Water Works Association

BMcD Burns & McDonnell

BMU Burns & McDonnell University

BPS Booster Pump Station

CCL Contaminant Candidate List

cfs cubic feet per second

cfu Colony Forming Unit

CIP Capital Improvements Plan/Projects

CPE Comprehensive Performance Evaluation

CWS Community Water System

DBP Disinfection Byproducts

DIP Ductile Iron Pipe

DMA District Metering Area

DOC Dissolved Organic Carbon

E. coli Escherichia coli

EBWF Equus Bed Well Field

<u>Abbreviation</u> <u>Term/Phrase/Name</u>

EDR Electrodialysis Reversal

EPA Environmental Protection Agency

EPS Extended Period Simulation

FBRR Filter Backwash Recycling Rule

fps feet per second

ft feet

FY Fiscal Year

GAC Granular Activated Carbon

gpm gallons per minute

gpmd gallons per meter-day

GWUDI Ground Water Under Direct Influence

HA Health Advisory

HAA Haloacetic Acids

HGL Hydraulic Grade Line

HPC Heterotrophic Plate Count

hr hour

HSPS High Service Pump Station

ICR Information Collection Rule

IDSE Initial Distribution System Evaluation

IESWTR Interim Enhanced Surface Water Treatment Rule

ILI Infrastructure Leakage Index

ILWSP Integrated Local Water Supply Plan

<u>Abbreviation</u> <u>Term/Phrase/Name</u>

IOC Inorganic Compound

ISO Insurance Services Office

IWA International Water Office

KAR Kansas Administrative Regulation

KDHE Kansas Department of Health and Environment

KWO Kansas Water Office

L Liter

LCRMR Lead and Copper Rule Minor Revisions

lf linear feet

LRAA Locational Running Annual Average

LT1ESWTR Long Term 1 Enhanced Surface Water Treatment Rule

LT2ESWTR Long Term 2 Enhanced Surface Water Treatment Rule

M/DBP Microbial/Disinfection Byproducts

MAPD Metropolitan Area Planning Department

MAPD Metropolitan Area Planning Department

MCL Maximum Contaminant Level

MCLG Maximum Contaminant Level Goal

MF Microfiltration

MG million gallons

mg milligram

MGD million gallons per day

MIB methylisoborneol

<u>Abbreviation</u> <u>Term/Phrase/Name</u>

min minute

MRDL Maximum Residual Disinfectant Level

MWTP Main Water Treatment Plant

NAS National Academy of Sciences

NCOD National Contaminant Occurrence Database

NDBA N-nitroso-di-n-butylamine

NDEA N-nitrosodiethylamine

NDMA N-nitrosodimethylamine

NDPA N-nitrosodi-n-propylamine

NDWAC National Drinking Water Advisory Council

NF Nanofiltration

nm nanometer

NMEA N-nitrosomethylethylamine

NPDWR National Primary Drinking Water Regulation

NPYR N-nitrosopyrrolidine

NSDWR National Secondary Drinking Water Regulation

NTU Nephelometric Turbidity Unit

NWTP Northwest Treatment Plant

O&M Operation and Maintenance

OEHHA Office of environmental Health Hazard Assessment

OEL Operational Evaluation Levels

OSG On-site Generation

<u>Abbreviation</u> <u>Term/Phrase/Name</u>

PAC Powder Activated Carbon

PCE Tetrachloroethylene

PFAA Perfluoralkyl Acid

PFAS Perfluoralkyl Substance

PFC Perfluorinated Compound

PFOA Perfluorooctanoic Acid

PFOS Perfluorooctane Sulfonate

PHG Public Health Goal

PODR Point of Diminishing Returns

PQL Practical Quantitation Level

PS Pump Station

PWS Public Water Supply

RAA Running Annual Average

RO Reverse Osmosis

RRW Recharge Recovery Well

RW Recharge Well

RWD Rural Water District

SCADA Supervisory Control and Data Acquisition

SDWA Safe Drinking Water Act

sf square feet

SMCL Secondary Maximum Contaminant Level

SMP Standard Monitoring Plan

<u>Abbreviation</u> <u>Term/Phrase/Name</u>

SOC Synthetic Organic Compound

SSS System Specific Study

Stage 1 D/DBPR Stage 1 Disinfectants/Disinfection Byproducts Rule

Stage 2 D/DBPR Stage 2 Disinfectants/Disinfection Byproducts Rule

SUVA Specific Ultraviolet Absorption

SWTR Surface Water Treatment Rule

T&O Taste & Odor

TBD To Be Decided

TC Total Coliform

TCE Trichloroethylene

TCR Total Coliform Rule

THM Trihalomethane

TOC Total Organic Carbon

TT Treatment Technique

TTHM Total Trihalomethane

UCM Unregulated Contaminant Monitoring

UCMR Unregulated Contaminant Monitoring Rule

UF Ultrafiltration

US United States

USEPA United States Environmental Protection Agency

UV254 Ultraviolet Absorption at 254 nm

VOC Volatile Organic Compound

Abbreviation <u>Term/Phrase/Name</u>

WDA Water Demand Assessment

WMP Water Master Plan

WRP Water Resources Plan

1.0 EXECUTIVE SUMMARY

1.1 Introduction

The 2016 Water Master Plan (WMP) updates the existing water distribution system hydraulic model to evaluate current and future conditions to develop capital improvement projects for the year 2020, 2035, and 2045 planning periods. Other modelling efforts include an update to the raw water model to evaluate maximum flows from the EBWF and Cheney supply systems under varying conditions and model development of the Hess reservoir system to evaluate water age and recommend improvements. Facility master planning for the raw water system, water treatment plant (WTP), and water distribution system employs capacity-based assessments, prepares redundancy and reliability recommendations, includes a regulatory compliance review, emergency planning considerations, and a water conservation review and recommendations.

1.2 Water Demand

The City developed water demand projections as part of the 2015 Water Resources Plan and includes a 1 percent drought and targets a 0.35 percent conservation effort through year 2060. In 2014, the City decided on a 1 percent drought tolerance to provide greater water supply resiliency. Water conservation is also part of the City's long-term strategy to reduce the need for a new water supply source. Additionally, conservation efforts have reduced the base demand over the last 5 years as stated in the Water Resources Plan. A maximum day to average day factor of 1.80 in each planning period is representative of the meter-based water demand projection discussed in Section 3.0. The average day and maximum day demand projections developed in the Water Resources Plan are listed below:

- 2016 at approximately 66 MGD and 118 MGD respectively.
- 2020 at approximately 67 MGD and 120 MGD respectively.
- 2035 at approximately 70 MGD and 127 MGD respectively.
- 2045 at approximately 71 MGD and 128 MGD respectively.
- For information only, in 2060 at approximately 72 MGD and 129 MGD respectively.

Meter-based average day and maximum day demand projections were also developed for comparison and, in some respect, provide an independent validation the Water Resources Plan projections discussed above. The meter-based projections for each planning period are listed below:

- 2016 at approximately 62 MGD and 114 MGD respectively.
- 2020 at approximately 63 MGD and 115 MGD respectively.
- 2035 at approximately 70 MGD and 125 MGD respectively.

• 2045 at approximately 75 MGD and 129 MGD respectively.

After review of the meter-based water demand projections and comparison with the Water Resources Plan, City staff concludes the projections from Water Resources Plan are adequate for the hydraulic modeling and evaluation for the development of capital improvements in this Water Master Plan.

1.3 Water Distribution System

1.3.1 Hess Pressure Zone Pumping

Pressure control is very important to the City's operation of Hess HSPS as water main breaks in the downtown area have occurred when pressure increases above 93 psi at Central and Main, therefore, the City has a target pressure of 92 psi. Under maximum day and peak hour demands, model results indicate the pressure at the HSPS and at Central and Main is approximately 99 psi and 92 psi. Hess HSPS has the operational flexibility to maintain the target pressure as system demands approach 154 MGD (peak hour) by a combination of the actions listed below. These actions are typically performed daily by WTP operators as the system is controlled manually:

- Running a combination of higher head pumps (Nos. 1, 2, 3, 4, 6, or 8) at a constant reduced speed with the VFDs;
- Running a combination of higher head pumps at full speed and one higher head pump with a
 VFD to deliver varying rates of flow at an operator-selected constant discharge pressure;
- Lowering the operating level in the Roosevelt and Woodlawn towers to mitigate drafting and reduce the pressure or hydraulic gradient in the distribution system; and
- Adjusting the sleeve valve at Webb Road reservoir to sustain higher upstream pressure;
 - Sleeve valve adjustments that increase the upstream pressure result in lower flows into
 Webb Road reservoir.
 - O Supplying the Northeast pressure zone entirely from Webb Road PS (37th St BPS off); this will increase turnover in the reservoir, but this in turn requires a longer time to replenish the volume exhausted by peaking demands in the Northeast pressure zone. Interstitial flows and/or demand conditions that cannot be delivered by Webb Road PS alone will require use of 37th BPS.

Other measures that should be considered for further evaluation in terms of pressure control include expanding the East pressure zone into Hess pressure zone; this would also increase the operating potential of Southeast BPS service in the East pressure zone.

The pumping capacity at Hess HSPS can adequately supply the 2016 projected minimum hour, maximum day, and peak hour demands required by the system of 55.6 MGD, 114.1 MGD, and 154.0 MGD respectively.

1.3.2 East Pressure Zone Pumping

Currently, Webb Road PS is the primary supply mechanism serving the East pressure zone and is controlled by discharge pressure, targeting between 55 psi and 65 psi at the pump under varying rates of flow. WTP operators also monitor pressure at the intersection of Kellogg Drive and Webb Road which is at a higher elevation of approximately 1,367 feet (70th percentile with respect to the entire pressure zone) and has historically experienced lower pressure than the remainder of the East pressure zone; therefore, it is used as a secondary operational control point.

The pumping capacity at Webb Road PS is adequate to deliver the projected 2016 maximum day and peak hour demands of 16.5 MGD and 22.4 MGD respectively to the East pressure zone. The pumping capacity at Southeast BPS is adequate to deliver approximately half of the maximum day demand, 8.3 MGD, in parallel with one pump at Webb Road PS; however, this is not recommended because the pump pushes to the left and higher up on the pump curve resulting in a discharge pressure of approximately 120 psi and increases system pressure by approximately 20 psi in the East pressure zone. Southeast BPS is better suited to deliver approximately half of the peak hour demand in parallel with one pump at Webb Road PS without exceeding tolerable pressure increases, approximately 10 psi, at Webb Road PS and at the intersection of Kellogg and Webb Road. Model results indicate a discharge pressure of approximately 107 psi at Southeast BPS under peak hour demand conditions.

City staff and WTP operators reported difficulties operating the Southeast BPS that are potentially caused by recycling water back into Hess pressure zone – when the BPS was in service there was minimal increase in discharge pressure. Modeling results validate this theory and is likely caused by an open pressure zone boundary valve or multiple valves that should normally be closed to isolate the Hess and East pressure zones. Southeast BPS was designed to pump into a closed pressure zone when demands are high and bypass flow during low and moderate demand periods. The bypass line and valves in the pump station should also be checked to confirm there is no reverse flow when the BPS is in service.

The Southeast BPS was installed to address low pressures south of Kellogg and Webb and in neighboring areas west of this intersection in the Hess pressure zone, meet the projected and expansive growth in the

East pressure zone, and transfer of customers from the Hess pressure zone through a western expansion of the East pressure zone. Prior to 2006, pressures near the intersection of Kellogg and Webb were approaching 20 psi during peak demands. Future growth that was expected to occur beyond the northern and southern limits of the existing distribution system has been marginal and recommendation to expand the East pressure zone into the Hess pressure zone about 3 miles west to Edgemoor Street was not implemented, which would have also increased East pressure zone demand. While these conditions are working against the intended purpose, the model indicates the Southeast BPS pumps current use should be limited to higher peak hour demands in parallel with Webb Road PS.

1.3.3 Northeast Pressure Zone Pumping

Webb Road PS is the primary water supply mechanism for the Northeast pressure zone and 37th Street BPS provides peaking assistance during high demand periods on an as-needed basis. Webb Road PS pump selection is based on maintaining a pressure of approximately 50 psi at the intersection of 34th and Webb Road. The pumping capacity at Webb Road PS can adequately supply the projected 2016 minimum hour, maximum day, and peak hour demands of 4.1 MGD, 8.4 MGD, and 10.3 MGD respectively assuming the published curves can be operationally replicated. No conclusions can be drawn on the pumping capacity of BDP-2 (Webb Road PS) because the SCADA historian data suggests the pump curve has shifted. Similarly, no conclusions can be drawn on the 37th Street BPS pumping capacity because the SCADA historian data suggests the pump curves have shifted or are being influenced by the mechanical governor on Pump No. 1. New pumps at Webb Road PS are currently being designed by others and will be evaluated in the future planning period model scenarios; however, if the new pumps are not installed within a year at Webb Road PS, then pump testing should be performed on each pump to develop new curves and compared to the published curves. Whether new or existing pumps reside at Webb Road PS, all pumps at 37th Street BPS should be tested to develop new pump curves. If pump testing results in pump curves like the published pump curves, then investigative efforts should include the following:

- Calibration confirmation of pressure transducers (suction and discharge) and flow meters at each pump station;
- Confirm the pressure zone boundary isolation;
- Confirm all valves that should be opened in each pump station are fully open;
- Confirm full valve closure on bypass pipes when Webb Road and Southeast BPSs are in service –
 bypass pipe valve status is conditional based on what pumps are running; and
- Confirm full valve closure on bypass pipes, if present, at wholesale customer connections and confirm reverse flow is not permitted from wholesale customer systems.

1.3.4 West Maple Pressure Zone Pumping

The pumping capacity of West Maple BPS can adequately supply minimum hour, maximum day, and peak hour demand conditions of 50 gpm, 104 gpm, and 140 gpm respectively. Model results simulating the 1-inch pipe connection from the discharge header to the suction header indicate the pump recycles water within the pump station effectively causing the pump to deliver more flow than is required by the pressure zone demand at a lower head. Since the pipe is small enough, the amount of water recycled through the pump station is marginal, and any decrease in discharge pressure affecting the pressure zone maybe unnoticeable. If water demand in West Maple pressure zone increases and diurnal patterns become more stable, for example consistent minimum hour and peak hour factors greater than 0.5 and less than 2.0 respectively, then the effectiveness of this pipe should be evaluated to determine if it is necessary. Conversely, if water demands increase and diurnal patters continue to be widely variable, then the size of the connection should be evaluated to determine if a larger diameter enhances pump station operation.

1.3.5 Water Main Hydraulics

Over 99.9 percent of all pipes evaluated in the model comply with velocity and headloss criteria. The remainder of pipes have a velocity either exceeding 5.0 fps or headloss greater than 6 ft per 1,000 ft, but not both, and has a marginal impact on the capacity and performance of the distribution system under maximum day and peak hour demand conditions. The model results for water main hydraulics indicate the existing distribution system is robust, acceptable headloss for the demand conditions evaluated, and has adequate capacity to convey minimum hour, maximum day, and peak hour demand conditions.

1.3.6 Available Fire Flow

The model is used to evaluate the available fire flow at all junctions at a residual pressure of 20 psi under the maximum day demand of 114.1 MGD. There are approximately 19,350 junctions in the existing distribution system model and each junction is assigned a fire flow of 1,000 gpm. The adequacy of the distribution system to convey fire flows can be characterized by the number of junctions resulting in available fire flow less than 1,000 gpm. Only 70 junctions, or 0.4 percent of all junctions, result in available fire flows less than 1,000 gpm and only about 20 junctions, or 0.1 percent of all junctions, result in flows less than 800 gpm. Typically, residential fire flow needs can be satisfied with 750 to 1,200 gpm. Areas with fire flows ranging between 750 gpm and 1,000 gpm are listed below:

- Dead end water mains in the West Maple pressure zone;
- The area northwest of the Central Ave and Webb Rd intersection in the Hess pressure zone; this is the eastern periphery of Hess pressure zone; and,

 Dead end water mains southeast of the Butler Rd and SW 120th St intersection in the East pressure zone; this is the eastern periphery of the East pressure zone.

1.3.7 Water Age

The water quality analysis computes water age in the distribution system to evaluate residence time in tanks and assist in predicting areas in the distribution system with the greatest potential for water quality deterioration. EPS model scenarios evaluate water age under average day and maximum day demand conditions of 62.0 MGD and 114.1 MGD respectively. Distribution system areas resulting in the highest water age under average day demand conditions include the periphery Hess pressure zone, most of the Northeast pressure zone, and the eastern and southern periphery of the East pressure zone, which, by all accounts, is expected as the majority of the distribution system functions as a closed system and these areas are the furthest from the WTP. The average water age over the entire distribution system under average day demand conditions is approximately 2.9 days (69 hours). The average water age under average day demand conditions for each pressure zone is listed below:

- Hess Pressure zone = 2.5 days (61 hours);
- East pressure zone = 3.7 days (88 hours);
- Northeast pressure zone = 4.8 days (114 hours); and
- West Maple pressure zone = 7.4 days (177 hours).

The average age over the entire distribution system based on maximum day demand conditions is approximately 2.7 days (64 hours). The distribution system locations resulting in the highest water age under maximum day demand conditions include a smaller area of the vicinities described above for the average day demand.

1.3.8 Storage

A summary of the storage evaluations, based on the current maximum day demand for each pressure zone, for the following operating conditions are as follows:

- Uninterrupted WTP production supplying the Hess reservoir system:
 - Northeast pressure zone has adequate effective storage to satisfy the minimum storage requirement (fire plus equalization). There is approximately 1.35 days (32.4 hours) of storage that can be allocated for emergency use or the City could reduce the active storage in Webb Road reservoir depending on the desired amount of emergency storage.
 - East pressure zone has adequate storage in the Hess reservoir system to satisfy the minimum storage requirement and approximately 0.21 days (5.2 hours) of emergency

storage based on its respective storage allocation. Based on the pumping capacity with backup power, Webb Road PS could deliver a 24-hour demand of approximately 11.6 MGD that would include a peaking demand of 25.0 MGD. If the City desired an effective pumping capacity with backup power to exceed the maximum day or peak hour demand in addition to fire flow, then backup power for one pump at Southeast BPS is required.

- O Hess and West Maple pressure zones have adequate effective storage in the Hess reservoir system to satisfy the minimum storage requirement and approximately 0.25 days (6.1 hours) of emergency storage. Hess HSPS has adequate effective pumping capacity with backup power to deliver peak hour plus fire flow requirements in Hess pressure zone.
- Loss of WTP production and a finite volume in the Hess reservoir system:
 - Collectively, the Hess, East, and West Maple pressure zones have adequate effective storage in the Hess reservoir system to satisfy the minimum storage requirement and approximately 0.2 days (4.8 hours) of emergency storage. Restoring the vacuum priming system is recommended to optimize the amount of emergency storage in Hess Reservoir system if pumps need to be started below a water level of 7.0 ft. There is marginal ability to lower the active storage volume in Hess Reservoir system with the amount of emergency storage available based on a minimum water pumping level of 4.0 ft.

The latter emergency condition that considers loss of WTP production is evaluated to raise questions for the City to address such as:

- What conditions could eliminate water treatment and could they be addressed and/or restored in 4.8 hours (0.2 days) or less?
- Can raw water be disinfected and diverted directly to the Hess Reservoir system?
- When will the City institute emergency water use restrictions?

1.3.9 Hess Reservoir System Hydraulics

Collectively, the model results show that the reservoir system exhibits adequate turnover based on the 2015 and 2016 average day and maximum day demand conditions. Individually, however, the 9.7 MG reservoir does not meet the low-end turnover volume requirement of 2.4 MG. Model results for water age at Hess HSPS is approximately 22 hours (at pump suction header) based on the 2015 average day demand of 49.7 MGD; the water age for each reservoir is listed below:

• 3.0 MG reservoir at 4 hours;

- 4.3 MG reservoir at 11 hours;
- 7.5 MG reservoir at 14 hours;
- 10.6 MG reservoir at 15 hours; and
- 9.7 MG reservoir at 16 hours.

The low turnover volume in the 9.7 MG reservoir simulated in the model supports the low disinfectant residuals the City has detected in the reservoir system. Lower turnover results in higher water age and lower disinfectant residual and higher turnover results in lower water age and higher disinfectant residual. Model results indicate the highest reservoir water age can occur in either the 10.6 MG Reservoir or the 9.7 MG Reservoir, which is a result of the demand and corresponding water level variation in each reservoir which is influenced by the headloss in the piping system, the forced flow pattern through reservoir system, and the diurnal curve. In 2016, City staff collected the following residuals in each reservoir:

- 3.0 MG reservoir at 3.08 mg/L;
- 4.3 MG reservoir at 2.9 mg/L;
- 7.5 MG reservoir at 0.80 mg/L;
- 10.6 MG reservoir at 0.60 mg/L; and
- 9.7 MG reservoir at 0.32 mg/L.

The reservoir model can be improved with calibration efforts to confirm water age, turnover results, and determine viability of passive and/or active mixing system applications. Additional information needed for calibration is water level trending and flows in/out of each reservoir. Currently, the only data available collected by the SCADA system is the chlorine contact basin level, suction pressure at Hess HSPS, and flow out of Hess HSPS. Using water levels and flow trends in each reservoir to calibrate the model will accurately simulate the headloss in the yard piping system, which in return, provides a better approximation of likely flow contributions from each reservoir under different demand conditions. This will help identify the system demand that fosters adequate turnover and inform City staff and WTP operators when to implement the first option (submersible pump recycle option) to improve disinfectant residuals discussed in the paragraph below the bulleted list. The following tasks are recommended in the order they are listed:

- Grab sample testing at each reservoir and at multiple locations in each reservoir where possible.
 - Based on the measurements and decay rate evaluation, assess mixing system alternatives and viability of alternatives in reservoirs not meeting adequate results.

 Depending on the grab sample test results, prepare a field testing plan to collect water level trending in each reservoir during peak summer time and low winter time demand conditions to capture minimum and peak flow conditions.

- Conduct calibration verification modeling to confirm water age and turnover results.
- Water level trending data is required to determine the applicability of passive and/or active mixing system applications in eligible reservoirs, as part of the mixing capability is based on maximum and minimum filling/drafting rates.

Options to decrease water age in the reservoir system while maintaining adequate turnover without infringing on minimum storage requirements for the distribution system are limited based on the existing yard piping, land availability, and reservoir arrangement. One option includes installing submersible pumps in the 9.7 MG and 10.6 MG reservoirs, which have the lowest turnover and highest water age per the model results and lowest disinfectant residuals per City staff, and pumping it to the 3.0 MG reservoir to blend and recycle the water, thereby lowering the overall water age in the reservoir system and forcing much needed turnover in the 9.7 MG and 10.6 MG reservoirs.

Another option to decrease water should evaluate and/or determine if any influent piping modifications within the HSPS can be made to facilitate better turnover in the reservoirs with lower chlorine residuals, and if so, update the model for validation.

Another option to decrease water age in the reservoir system is consolidating all 35.1 MG of storage into a single well baffled reservoir and providing hydraulic similitude in the yard piping between the reservoir and the influent pipes of Hess HSPS is a potential option to lower water age in the system and increase turnover. Capital cost and constructability factors need to be assessed to determine the viability of this option and consider site restrictions and limitations, construction time, and the ability to maintain adequate storage during construction in the reservoir system for what may only be a slight improvement in water age and turnover above what is currently adequate; however, a single well baffled reservoir with bifurcation (multiple storage cells) would provide optimal operational flexibility and allow City staff to shut down a storage cell for cleanout or shut down a cell during periods of low demand when the storage is unnecessary.

1.3.10 Future Growth

Population projections through year 2045 are allocated to the future growth areas. The anticipated growth pattern provided by the City and MAPD places more emphasis on infill utilization than future

development beyond the City's existing water service area, but neither is a prerequisite for the other. Growth of either type, infill or development, can happen at different rates and at different times. Since the anticipated rate at which each growth area reaches buildout capacity was not provided, the population allocation for future growth assumes infill utilization occurs before future development beyond the City's existing water service area. Infill growth represents approximately 71 percent of the total growth area and peripheral growth represents approximately 29 percent. The maximum day demand allocations per planning period and by pressure zone for future growth areas only are listed in Table 1.1. The population projection and total average day and maximum day demands (includes existing system and future growth areas) and summarized below:

- Year 2020
 - o Population at 416,652; and
 - Average and maximum day demands at 67 MGD and 120 MGD respectively.
- Year 2035
 - Population at 485,483; and
 - Average and maximum day demands at 70 MGD and 127 MGD respectively.
- Year 2016
 - o Population at 537,603; and
 - Average and maximum day demands at 71 MGD and 128 MGD respectively.

1.3.11 Year 2020 Planning Period

The water demand projections and corresponding demand conditions for the year 2020 planning period are listed below and require approximately 2.4 miles of linear hydraulic related improvements and 4.1 miles of fire flow related improvements to support infill growth within the City's existing water service area:

- Maximum Day = 120 MGD
- Peak Hour = 153 MGD
- Minimum Hour = 59 MGD

There are no pumping improvements required to meet the projected water demands as all pump stations collectively serving their respective pressure zones have adequate pumping capacity to deliver the peak hour and maximum day plus fire flow demand conditions while maintaining pressures greater than 40 psi. Southeast BPS can be used under peak hour demand conditions and, as a result, the discharge pressure at Webb Road PS (East pressure zone pumps) increases to 74 psi, which is 9 psi higher than the current desired range between 55 psi and 65 psi. The average pressure in the East pressure zone under peak hour

Table 1.1
Future Growth Maximum Day Demand Allocation per Planning Period

Year	Pressure Zone (MGD)								Subtotal Demand (MGD)				T-4-1 D1 ¹
	Hess		East		Northeast		West Maple		Infill	Peripheral	Wholesale	Spirit	Total Demand
	Infill	Peripheral	Infill	Peripheral	Infill	Peripheral	Infill	Peripheral	1111111	Peripilerai	wilolesale	Jpirit	(MGD)
2016	0.7		0.3		0.0		0.0		1.2		7.0	2.5	10.7
2020	2.8		1.3		0.2		0.1		4.5		7.0	2.5	14.0
2035	10.5		4.7		0.6		0.2		17.2		7.0	2.5	26.7
2045	0.7	7.8	0.3	1.7	0.0	0.7	0.0		1.6	10.2	7.0	2.5	21.3

Notes:

1. This demand only represents the future growth areas.

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demands is approximately 89 psi with Southeast BPS on; if the BPS is off and all demand is served by Webb Road PS, then a large area south of Harry Street and east of Greenwich Road experiences low pressure between 25 psi and 35 psi.

Firm capacity is considered the pumping capacity with the largest pump out of service. With respect to the Northeast pressure zone, the firm capacity of Webb Rd PS (based on new pumps to be installed in 2017) is approximately 6,500 gpm, which is less than the 2020 maximum day demand of 6,800 gpm. Therefore, flow from 37th St BPS must be relied on to supplement firm capacity conditions for the Northeast pressure zone. As indicated in Section 6.1.3, no conclusions could be made on the pumping capacity of 37th St BPS because SCADA historian data suggests the pump curves have shifted or are influenced by the mechanical governor on Pump No. 1 and should be tested. The results of the pump tests (new pump curves) should be evaluated in the model to determine hydraulic compatibility with Webb Rd PS before determining the need for new pumps, sizing recommendations, and/or the ability of the pump station to support different size pumps based on the year 2045 maximum day demand of 10.8 MGD. New pumps sized at varying flow rates may provide more operational flexibility, versus new pumps each with the same capacity, to meet the range of demands experienced in the Northeast pressure zone and support firm capacity conditions; head conditions for new pumps should be able to overcome headloss in the pressure zone and reach the overflow elevation of the Northeast Tower.

The storage analysis for the Northeast pressure zone is evaluated alone because it has dedicated storage in Webb Road reservoir and in the Northeast Tower (effective storage). Hess, East, and West Maple pressure zones have shared storage at Hess reservoir and are evaluated together. Results of the storage analysis indicate a surplus of 9.7 MG for the Hess, East, and West Maple pressure zones and a storage surplus of 5.7 MG for the Northeast pressure zone; no additional storage is required in the distribution system.

There are 17 capital improvements with hydraulic triggers required to support the year 2020 demand projection and infill growth; 14 of these are smaller projects, each less than 200 ft in length, and are attributed to undersized parallel water mains that exhibit velocity greater than 5 fps and headloss greater than 6 ft per 1,000 ft. The headloss is manageable and does not impact distribution system hydraulics greatly, but higher velocities can result in water main breaks during periods of accelerated flows through the system such as fire flow. The larger projects include the following:

• 2020-Hess-H-16: approximately 1,000 feet of 48-inch pipe is required to convey flow into the southern and eastern parts of Hess pressure zone, notably the suction side of Southeast BPS.

This improvement ties into the end of the existing 48-inch transmission main at the intersection of Lewis Street and Green Street and connects to CIP 2020-Hess-H-12 discussed below.

- O 2020-Hess-H-12: approximately 2,900 feet of 30-inch pipe is required to convey flow into the southern and eastern parts of Hess pressure zone, notably the suction side of Southeast BPS. This improvement ties into CIP 2020-Hess-H-16, heads south down S Erie Street, east for a short run on E Kellogg St, then south along Lorraine Street and ties into the existing 30-inch water main on Morris Street.
- 2020-Hess-H-15: approximately 5,200 feet of 30-inch pipe is required to convey flow from Hess
 pressure zone to the suction side of Southeast BPS and ties into the existing 24-inch at the
 intersection of Lincoln Street and Woodlawn Street, heads south down Woodlawn then east
 along Harry Street to the 36-inch suction pipe on Governeour Rd.
- 2020-East-H-2: approximately 3,500 feet of 30-inch pipe is required to convey more flow from Southeast BPS down Harry Street. This water main ties into the existing 30-inch water main on Harry Street near Harry Court and extends east down Harry Street and ties into the 20-inch and 16-inch water mains at the intersection of Harry Street and Webb Road.

City staff indicated potential large users often consider the industrial area near the intersection of S Tyler Road and W 31 Street S for their needs; therefore, an additional model simulation determined the available flow by increasing the recommended size of 12-inch to a 16-inch for CIPs 2020-Hess-H-18 (PIPE639) and 2020-Hess-H-19 (PIPE641) for comparison. Pressure at this location under maximum day demand conditions is approximately 74 psi; assuming an allowable pressure drop of 5 psi, which is tolerable for this area of the distribution system, the resulting flow, or demand, for each size is listed below:

- 12-inch (as listed in the CIP) can deliver approximately 1,170 gpm.
- 16-inch can deliver approximately 1,260 gpm.
- Base on the results of this analysis, a 16-inch conveys 90 gpm more to this area, therefore, the recommendation for a 12-inch is maintained in the CIP.

Capital improvement projects with fire triggers total approximately 4.1 miles in length and increase the available fire flow range in adjacent areas between 800 gpm and 1,200 gpm and is adequate for the residential neighborhoods in which they are located. The fire flow improvements listed below have additional discussion points for the City to consider:

• 2020-Hess-F-11, 2020-Hess-F-13, and 2020-Hess-F-14: these 12-inch improvements total approximately 2.0 miles and primarily serve to increase fire flow; looping is an added benefit

around Explorer Elementary School, Apollo Elementary School, Eisenhower Middle School, and Eisenhower High School. Fire hydrant testing should also be conducted during peak demand conditions when all schools are in session. The fire flow requirements may exceed typical residential needs of 1,000 gpm and should be determined by the fire marshal or the governing authority. If the fire flow test results are adequate, then these improvements are not required until future development occurs in these areas. If the fire hydrant testing is inadequate and the proposed lines are needed to meet the fire flow requirement, then the City should consider implementing automatic flushing devices on hydrants connected to this loop to maintain water quality and decrease water age. The model results indicate very little to no flow in these improvements under maximum day and peak hour demand conditions.

1.3.12 Year 2035 Planning Period

The water demand projections and corresponding demand conditions for the year 2035 planning period are listed below and require approximately 1.2 miles of linear hydraulic related improvements and pumping improvements at two BPS to support infill growth within the City's existing water service area. The hydraulic and fire flow related improvements recommended in the 2020 planning period are adequate for the fire flow needs of the 2035 planning period; therefore, there are no fire flow related improvements.

- Maximum Day = 127 MGD
- Peak Hour = 171 MGD
- Minimum Hour = 62 MGD

Pumping improvements required to meet the projected water demands include one pump at West Maple BPS and one pump at Southeast BPS. The West Maple BPS pump should be sized to match the existing pumps at 537 gpm at 111 feet of pump head. The additional flow required in this planning period is the result of expanding the West Maple pressure zone to include the area bound by Kellogg Avenue, South 135th Street West, and West Maple Street. The West Maple pressure zone expansion into the periphery of Hess pressure zone is relatively minor geographically, but it increases the pressure above 40 psi.

The Southeast BPS pump can be sized to deliver 24 MGD at 130 feet of pump head which will increase the firm capacity of the BPS to 24 MGD as designed. The existing smaller pump(s) at Southeast BPS are utilized under maximum day and peak hour demand conditions to supplement East pressure zone flow from Webb Road PS. Other pumps sizes, with respect to flow and head, can be evaluated if it provides more operational flexibility and increases BPS usage, but efforts to reincorporate this BPS with the smaller pumps should be done first (before implementing the 24 MGD pump) to determine its ability

and/or inabilities since the demand conditions it was designed for have changed extensively. All other pump stations have adequate pumping capacity to deliver the peak hour and maximum day plus fire flow demand conditions.

Results of the storage analysis indicate a storage surplus of 9.0 MG for the Hess, East, and West Maple pressure zones and a storage surplus of 5.5 MG for the Northeast pressure zone; no additional storage is required in the distribution system. Under minimum hour demand conditions and/or low flow periods at night, lasting 4 to 5 hours, the distribution system and Hess HSPS is capable of filling Webb Road reservoir, Woodlawn Tower, and Roosevelt Tower. Additionally, the distribution system and new pumps at Webb Road PS serving the Northeast pressure zone have adequate capacity to fill the Northeast Tower during low demand periods.

There are ten capital improvements with hydraulic triggers to support the year 2035 demand projection and infill growth; nine of them these are smaller projects, each less than 200 ft in length and are attributed to undersized parallel water mains that exhibit velocity greater than 5 fps and headloss greater than 6 ft per 1,000 ft. The headloss is manageable and does not impact distribution system hydraulics greatly, but higher velocities can result in water main breaks during periods of accelerated flows through the system such as fire flow. The largest project is listed below:

 2035-Hess-H-8: approximately 3,800 feet of 16-inch pipe is required to convey flows into the southwestern parts of Hess pressure zone and west of Interstate 235. This improvement parallels the existing 20-inch water main on West Maple Street from South Ralstin Road to Woodchuck Street.

1.3.13 Year 2045 Planning Period

The existing distribution system and the capital improvements recommended in the 2020 and 2035 planning periods are adequate to support the water demand projections for the year 2045. The water demand projections and corresponding demand conditions for the year 2045 planning period are listed below and require approximately 77.6 miles of linear development driven improvements to support infill growth and peripheral growth beyond the City's existing water service area.

- Maximum Day = 128 MGD
- Peak Hour = 175 MGD
- Minimum Hour = 63 MGD

The hydraulic and fire flow related improvements recommended in the 2020 and 2035 planning period are adequate for the fire flow needs of the 2045 planning period; therefore, there are no fire flow related improvements. Furthermore, the distribution system does not require any pumping or storage improvements. Results of the storage analysis indicates a storage surplus of 8.8 MG for the Hess, East, and West Maple pressure zones and a storage surplus of 5.5 MG for the Northeast pressure zone.

While the water service area does expand beyond the existing limits in year 2045, there is only marginal increase in the water demand projections compared to the year 2035 of about 1 MGD for maximum day. Water main projects totaling 12 miles to support future growth in Andover is included in the model, but are not represented as capital improvements in the CIP. These projects are anticipated to be initiated by the developer and funded by Special Assessments or Private Projects improvements as indicated by City staff.

1.3.14 Facilities Evaluation: Northeast Tower

When the Northeast Tower is placed in service, the Northeast pressure zone will transition from a closed system to an open system and require changes to the operational controls at Webb Road PS. The current mode of operation at Webb Road PS utilizes the VFDs to maintain a constant discharge pressure and/or pressure range at 34th Street and Webb Road under varying rates of flow and utilizes 37th Street BPS in a supplementary role for flow support. When the Northeast Tower is placed in service, the Webb Rd PS pumps should be run at constant speed or constant reduced speed and cycle on and off based on operator pre-set levels in the Northeast Tower.

Establishing operational controls for Webb Road PS to interact with the Northeast Tower also must consider tank turnover in addition to the fire protection and equalization storage needs of the pressure zone as well. The recommended tank turnover to maintain water quality and prevent high water age ranges from 25 percent to 33 percent of the total volume daily. Applying the low-end turnover recommendation of 25 percent represents 10 ft within the 40 ft head range of the tower. Based on the equalization demands, fire storage needs, and recommended turnover volume of the Northeast Tower, the control points for Webb Road PS are listed below:

- Maintain a minimum water level of 25 ft in the tower for fire protection;
- Pump or pumps on at 26 ft (depending on how fast staff wants to/can fill the tower, two pumps can by cycled on concurrently, this maybe a seasonal adjustment); and
- Pump or Pumps off at 36 ft.

The pumps can also be operated in a lead-lag manner to mitigate excessive drafting rates, greater than 1,500 gpm) from the Northeast Tower or additional pumps can be cycled on at 37th Street BPS if adequate information on the pump curves can be developed from pump testing. If the existing 37th Street BPS pumps cannot support Northeast pressure zone hydraulics with the new pumps at Webb Road PS and the Northeast Tower in service, then pump replacement should be considered. For clarity, these are recommended starting points and should be adjusted for current demand conditions.

Other impacts in the distribution system stemming from the Northeast Tower may alter normal, or current, operating levels in Webb reservoir. Webb reservoir serves multiple purposes and one of its more important functions is a buffering mechanism that allows operators to bleed off pressure in Hess pressure zone if they exceed 92 psi at Central and Main or bleed of excess flow if the Woodlawn or Roosevelt towers are nearly full. Since the Northeast Tower will serve as the supply mechanism for equalization demands and Webb reservoir will no longer need to, the operating range of the reservoir may need to be lowered to continue serving as a buffering mechanism.

In conclusion, peaking demands are provided by the Northeast Tower; therefore, Webb reservoir storage turnover will decrease and potentially limit its ability to receive water from Hess pressure zone; to combat this, the operating range of Webb reservoir should be adjusted concurrently as the Northeast Tower is placed in service. In which case, the storage evaluation for the Northeast pressure zone in Section 6.0 identifies what the reservoir levels can be lowered to (with consideration to the City's desired emergency storage volume at Webb reservoir). Based on the storage analysis presented (Table 11.3, see Section 11.0 for table), Webb reservoir needs to provide approximately 0.83 MG of storage for equalization for the year 2020 maximum day demand of 9.8 MGD.

1.3.15 Facilities Evaluation: Southeast BPS Control

City staff and WTP operators reported difficulties operating the Southeast BPS. These are potentially caused by recycling water back into Hess pressure zone as illustrated by the minimal increase in discharge pressure when the BPS was in service. An open pressure zone boundary valve, or multiple valves that should normally be closed to isolate the Hess and East pressure zones, or closed suction/discharge valves are potential causes.

The Southeast BPS was designed to address low pressures south of Kellogg and Webb and in neighboring areas west of this intersection in the Hess pressure zone, meet the projected and expansive growth in the East pressure zone, and transfer of customers from the Hess pressure zone through a western expansion of

the East pressure zone. Future growth that was expected to occur beyond the northern and southern limits of the existing distribution system has been marginal. For perspective, the year 2020 planning period is common in the 2003 Water Master Plan and this master plan; a comparison of the demand conditions for the East pressure zone is listed in Table 1.2 below. Review of the demand projections show a 48 percent reduction of the maximum day demand and a 62 percent reduction of the peak hour demand from in 2003 Water Master Plan projections for the year 2020.

Table 1.2 - East Pressure Zone Demand Projections

Water Master Plan	Planning Period	Maximum Day (MGD)	Peak Hour (MGD)		
2016	2020	19.3	24.5		
2003	2020	36.8	63.5		

In 2003 the average and maximum day demands in the East pressure zone were estimated at 6.1 MGD and 11.5 MGD respectively. Demands in the East pressure zone have remained consistent and in 2015 the maximum day demand was less than that experienced in 2003; in 2015 the average and maximum day demands are estimated at approximately 7.2 MGD and 11.3 MGD.

The Southeast BPS is integrated in the maximum day and peak hour demand conditions of the 2020, 2035, and 2045 planning periods of the model to determine its service potential since the future growth plan and demand projections have changed significantly over the last 10 years. The model results validate its service potential and integrating the Southeast BPS back into the City's operations is recommended. However, based on the demand projections, its use is likely limited to peak hour conditions during high seasonal demand periods, and its service is expected to increase as water demands increase in the East pressure zone.

1.3.16 Recommendations for Additional Studies

Recommendations for additional studies include the following:

- Replace centralized storage in Hess Reservoir system with elevated storage in the distribution system to determine impacts on pressure zone delineation, distribution system hydraulics, changes in system operation, and support emergency storage goals desired by the City.
- Evaluate system hydraulics with expansion of the East pressure zone to determine if additional demand provides extended use of the Southeast BPS under demand conditions other than the maximum day and peak hour on the maximum day and determine impact of corresponding hydraulics and pressure control at Central and Main caused by Hess pressure zone contraction. This study should also include impacts of different pump sizes if it increases pump station use.

• Pump testing at 37th Street BPS to establish pump curves and summarize system conditions requiring its use to better define its long-term future with the integration of the Northeast Tower and new pumps at Webb Road PS serving the Northeast pressure zone. As indicated in Section 6.1.3, no conclusions can be drawn on the 37th Street BPS pumping capacity because SCADA historian data suggests the pump curves have shifted or are being influenced by the mechanical governor on Pump No. 1.

 Field testing and calibration of the Hess reservoir system hydraulic model, unless the option to recycle water from reservoirs with low disinfectant residual and minimal turnover to the 3.0 MG reservoir is selected.

1.4 Water Treatment

Multiple options are evaluated for water treatment planning and capital improvements and are based on triggers for capacity, redundancy, and safety considerations. Three options are detailed below and include the Base Option which addresses near-term and long-term capacity-driven improvements and Option No's. 1 and 2 which address redundancy-driven improvements:

- Base Option the year 2018 and 2020 deadline reflects starting on these improvements due to the high level of need:
 - Washwater Process Improvements: increases the washwater pumping capacity, additional piping, and new 3.0 MGD gravity sludge thickener. The trigger for this improvement is capacity and is recommended for completion by 2018.
 - o Filter Improvements: includes filter media replacement, filter underdrain replacement, backwash chlorination system, piping, valves, instrumentation, controls, and replacement of 48-inch, 36-inch, and 20-inch butterfly valves. These improvements increase filter capacity to 128 MGD with all filters in service. The trigger for this improvement is capacity and is recommended for completion by 2018.
 - New Vacuum Priming System at Hess HSPS: includes skid-mounted vacuum priming system, control, piping, and valves. The trigger for this improvement is replacement and is recommended for completion by 2018.
 - O Hess Reservoir Recirculation System: includes submersible pumps situated in the 9.7 MG and 10.6 MG reservoirs and discharge piping to the 4.3 MG reservoir, demolition, electrical, and miscellaneous structural improvements for top slab modifications. The trigger for this improvement is water quality and is recommended for completion by 2018.

 OSG for Disinfection: includes a storage building, hypochlorite generation equipment, storage tanks, instrumentation, controls, electrical, piping, and site work for completion by 2020.

• Option No. 1:

- NWTP: includes raw water storage, supply piping and headworks, clarification and softening, 13.3 MGD of RO, stabilization, filtration, disinfection and other chemical feed, finished water storage and pumping, residuals handling, RO concentrate disposals, and dedicated transmission from the NWTP to Hess Reservoir system. The trigger for this improvement is redundancy and is recommended for completion by 2035.
 - If Option 1 is selected, it is in addition to the recommended capital improvements in the Base Option.

• Option No. 2:

- Northwest WTP (NWTP); includes the same items listed for Option No. 1, except the dedicated transmission is replaced with additional transmission in the distribution system. The trigger for this improvement is redundancy and is recommended for completion by 2035.
 - If Option 2 is selected, it is in addition to the recommended capital improvements in the Base Option.

1.4.1 Facilities Evaluation: East WTP

The East WTP Improvements project is currently on-going and will provide clarification/softening facilities capable of treating up to 80 MGD of 100 percent groundwater or a blend of surface water and groundwater. This will dramatically improve water treatment flexibility and mitigate the risk of a temporary loss of Cheney water due to a transmission main issue or a severe drought. The existing facilities are not capable of treating 100 percent groundwater and, therefore, require a blend of surface and groundwater supplies for the treatment process. If the Cheney water supply is lost or out of service under the current treatment capability of the WTP, the City has a finite amount of time, based on the water demand, the number of filter cycles needed, and the volume of treated water stored in Hess reservoir system and at Webb Road reservoir, to continue delivering water to customers.

For clarity, filtration capacity will not increase with the East WTP Improvements project, therefore, the overall rated treatment capacity of the WTP will not increase. The rated capacity of the WTP will remain at 160 MGD, and the filtration improvements recommended above still need to be performed to achieve that capacity. Moving forward with the construction phase of the East WTP Improvements project is recommended as it improves capacity, flexibility, and lowers risk under drought conditions with minimal

or no surface water supply available. This project also provides more operational flexibility for decant transfer to both the East and Central plants, address the hydraulic bottleneck upstream of the filters if necessary, and more importantly, enable the City to treat 100 percent groundwater which enhances the flexibility of the City's treatment options of their raw water supply sources. Capital costs for these improvements are provided in that project and are not included in this report.

1.4.2 **New NWTP**

The 2015 Water Resources Plan by the City includes the future potential to supplement the existing WTP with an additional treatment facility located near the intersection of 21st and Zoo Boulevard; this is referred to as the Northwest Treatment Plant (NWTP). A new treatment facility at a location other than the existing WTP provides redundancy and mitigates risk associated with loss of treatment/production, but also carries with it an increased cost of operation to staff, operate, and maintain two WTPs and operational complexities of operating two WTPs during low and moderate demand periods.

The Central Plant is aging and requires major rehabilitation or complete replacement likely in the next 20 years. It is assumed, and likely, that the extent of the Central Plant improvements will not allow uninterrupted treatment service. Therefore, the NWTP is sized for 80 MGD to accommodate necessary Central Plant improvements and provide the level of system-wide treatment redundancy desired by the City in the year 2035. The NWTP trigger is not capacity driven, it's trigger is based on treatment redundancy. An added inherent benefit of the ability to treat and deliver water to the City's customers from multiple locations lessens the severity of any emergency and/or temporary condition that includes loss of treatment. Implementing the NWTP prior to rehabilitation of the Central Plant places its completion within the next 20 years, based on the age of the Central Plant and its condition as confirmed by City staff.

1.4.3 Regulatory Review

The Wichita WTP is currently meeting all State and Federal drinking water regulations. A summary of the compliance status for the comprehensive regulatory review is listed below:

- Primary and Secondary Drinking Water Regulations: based on the review of Wichita WTP lab
 data, none of the compounds regulated in the have exceeded the maximum contaminant levels
 (MCLs). Most IOCs, VOCs, and SOCs measured are below the analytical detection limit and all
 are below the MCL.
- Arsenic Rule: raw water arsenic concentrations from Cheney and EBWF raw water samples between 2010 and 2015 were found to be below the maximum contaminant level of $10 \,\mu\text{g/L}$. In 2014, Cheney and EBWF respectively measured 3.67 and 2.71 $\mu\text{g/L}$ and the distribution samples

ranged between 1.47 and 1.57 μ g/L. Data collected in 2015 showed slightly lower arsenic concentrations.

• Lead and Copper Rule: according to the City of Wichita's Consumer Confidence Reports and the reports issued to KDHE, the distribution system testing conducted in 2010 and 2012 indicate compliance with the provisions of the Lead and Copper Rule based upon the 90th percentile of home tap samples. In 2010, 51 tap samples were collected and analyzed for lead and copper and the 90th percentile for lead and copper was 0.007 and 0.086 mg/L, respectively. In 2012, 50 samples were collected and analyzed for lead and copper and the 90th percentile for lead and copper was 0.008 and 0.096 mg/L, respectively.

 Radionuclides Rule: according to the City of Wichita's Consumer Confidence Reports and data collected between 2010 and 2014, each radionuclide was below detection and in compliance with the Radionuclides Rule.

Radionuclide	Wichita WTP
Combined Radium	Below Detection
Total Beta Emitter	Below Detection
Gross Alpha	Below Detection
Uranium	Below Detection

- Radon Rule: according to the City of Wichita's Consumer Confidence Reports and data collected between 2010 and 2014, radon was detected at low concentrations, well below the 300 pCi/L.
 Therefore, the WTP is in compliance with the Radon Rule.
- Filter Backwash Recycling Rule: the WTP is in compliance.
- Surface Water Treatment Rule: the WTP is classified as a well-operated conventional WTP by
 meeting turbidity requirements less than 0.5 NTU and is credited with 2.5-log Giardia and 2-log
 of virus disinfection credit. Chlorine is added to meet 0.5-log Giardia and 2-log viruses. As a
 result, the Wichita WTP is currently in compliance with this rule.
- Disinfection: the WTP is able to achieve the required CT credit for 0.5-log Giardia and 2-log viruses with free chlorine using a chlorine contact basin. Monochloramine is formed after CT credit to maintain a residual in the distribution system. As a result, the Wichita WTP is in compliance with Federal and State disinfection regulations.
- Total Coliform Rule: microbial data collected between 2010 and 2014 were absent of E.coli. Total coliforms ranged between 1.08 percent (October 2010) and 3.03 percent (August 2012) of all samples collected. The monochloramine residual was higher than 2 mg/L for all distribution sites. As a result, the WTP is currently in compliance with each requirement of this rule.

• Interim Enhanced Surface Water Treatment Rule: average turbidity is less than 0.3 NTU in more than 95 percent of the samples. The Wichita WTP is in Cryptosporidium Bin 1 category, so no additional treatment credit is required. As a result, the Wichita WTP is currently in compliance with this rule.

- Long Term 1 and 2 Enhanced Surface Water Treatment Rule: data collected from 2010 through 2015 (April 1) show that the Wichita WTP is in category Bin 1. As a result, the City does not need to achieve any additional Cryptosporidium removal credits.
 - o If higher levels of Cryptosporidium are detected in the future, additional treatment will be required. The City can choose from an array of options listed in the "microbial toolbox". The microbial toolbox provides systems with flexibility in selecting cost-effective LT2ESWTR compliance strategies for Cryptosporidium. The draft Toolbox Guidance Manual provides general information on the LT2ESWTR regulation and treatment requirements (see Section 9.0 for additional toolbox information).
- Stage 1 Disinfectants/Disinfection Byproducts Rule: total Trihalomethane (TTHM) and
 Haloacetic Acid (HAA5) data for 2010 through 2014 are well below regulatory limits. HAA5 and
 TTHM values ranged between 7 and 15 μg/L and 15 and 28 μg/L in the distribution system,
 respectively. The Wichita WTP is in full compliance with regards to disinfection byproducts.
 - The distribution of DBP species was also evaluated. Of the HAA species, dichloroacetic acid and dibromoacetic acid are typically the highest and represent 80 percent of HAA5. Chloroform typically represents approximately 20 percent of the TTHM species, showing that bromide is present and having an impact resulting in the formation of the three brominated species. This data indicates that treatment is doing a good job with removing DBP precursor material.
 - O Disinfection Byproduct Precursor Removal: raw water TOC data for the Wichita WTP typically ranges between 3 and 8 mg/L. The raw water alkalinity is always greater than 120 mg/L; therefore, a 25 percent TOC reduction is required for most sampling periods, based on raw water TOC and alkalinity. The TOC reduction at the Wichita WTP ranges between 25 to 45 percent. As a result, the Wichita WTP is in compliance with regards to TOC reduction.
- Unregulated Contaminant Monitoring Rule: the UCMR2 contaminants are summarized below in Table 9.12. UCMR2 contaminant data was collected on June 22, 2009; October 21, 2009; January 21, 2010; April 04, 2010; and June 26, 2010. Finished water was below the detection limit for all samples collected.

Unregulated Contaminant Monitoring Rule (UCMR3): the data collected as part of UCMR3 show
that possible future regulatory requirements with regards to chromium, NDMA, PFAS, and VOCs
will have minimal impact on the WTP.

1.4.4 Recommendations for Additional Studies

Recommendations for additional studies include the following:

- Sludge thickener capacity;
- Sludge lagoon capacity and long-term planning recommendations;
- NWTP alternative treatment options and evaluation of processes to remove chlorides; and
- Evaluate the feasibility of converting to liquid ammonia at the MWTP.

1.5 Raw Water System

1.5.1 Hydraulic Analysis

The raw water model is used to evaluate pumping and transmission capacity and, based on the model results, no EBWF improvements are required. Raw water transmission from the Cheney and EBWF supplies have adequate capacity to convey approximately 160 MGD, but also require improvements to remove air from the Cheney transmission line. The transmission mains added in ASR Phase II allow the EBWF to convey upwards of 146 MGD if the well pumping capacity were installed.

The pumping capacity from the EBWF based on the current pump curves and groundwater levels indicates 80 MGD can be supplied; keeping in mind the model does not evaluate the operating condition of the wells or aquifer capacity. A well rehabilitation program is recommended, but is not considered a capital improvement, because well maintenance is essential to properly operate and sustain a reliable groundwater supply system. Water right 42824 provides conjunctive use with a maximum diversion rate of 80 MGD, therefore, additional water rights are not required.

The Cheney system has adequate pumping and transmission capacity if the air pockets are removed; however, increasing the pressure in the southern 66-inch transmission main from 21st and Zoo Boulevard to the WTP (Cheney supply) could cause additional main breaks under low flows or static conditions from Cheney PS that result in operating pressures greater than 80 psi which is the design operating pressure.

The proposed operational changes imparted by the East WTP Improvements project will increase the pressure on this line at the WTP from 65 to 102 psi at 20 MGD from Cheney PS and up to 108 psi under

static conditions (no pumps on at Cheney PS and Cheney surge tank nearly full). One option is a capital improvement that will enhance the redundancy and reliability of the Cheney supply while replacing an asset that is over 50 years old. These improvements include a 60-inch transmission main from Cheney PS to 21st and Zoo Boulevard to parallel this 50-year old line and a 66-inch transmission main from the EBWF to the WTP to parallel the 60-year old line. The parallel raw water transmission mains serve the following purposes:

- Transmission redundancy for both water supply sources;
- Removes risk of increasing pressure in the existing southern 66-inch transmission main that could potentially cause water main breaks;
- Allows the isolation valve separating the Cheney supply from the EBWF supply at the WTP to
 remain normally closed; this eliminates blending potential upstream of the WTP sleeve valves
 and supports the primary objective of the East WTP Improvements project which calls for 100
 percent groundwater treatment up to 80 MGD if surface water from Cheney is unavailable; and

A condition assessment of all raw water transmission mains is recommended before planning and engineering of the redundant/parallel transmission improvements to determine the following:

- Anticipated remaining useful life of each transmission main;
- Defect detection, leaks, air pockets, pipe material changes, damaged pipes, pipe stress, offset joints, cracks, corrosion, etc.; and
- Develop triggers, advantages, and disadvantages to determine if reinvestment in the existing
 transmission main, or sections thereof, is recommended or if new parallel transmission is
 recommended based on end goals, remaining useful life, and anticipated operating conditions.
- Determine whether or not it is better to replace the southern 66-inch transmission main (Cheney supply) and install a new transmission main from Cheney PS to the WTP.

An alternative to a redundant 66-inch transmission main from 21st and Zoo Boulevard to the WTP (Cheney supply) is providing pressure control on the 60-inch Cheney transmission main as previously recommended. A pressure control valve or structure upstream of the 21st and Zoo location will maintain water level in the Cheney surge tank and shear pressure below the design operating pressure (80 psi) of the southern 66-inch transmission main under low flows; this would alleviate the concern of increased pressures under low flow conditions from Cheney PS in conjunction with the operational changes imparted by the East WTP Improvements project. Under static conditions, with no flow from Cheney PS, the pressure control structure should include adequate isolation (valves) that maintain a positive water level in Cheney surge tank; isolation valves, coupled with vacuum breaker and air release, also removes

the static pressure head from Cheney surge tank on the southern 66-inch transmission main. If the pressure control structure and isolation valves are positioned near 21st and Zoo Boulevard, then under static conditions with isolation in effect, the pressure at the WTP is approximately 10 psi to 15 psi.

The pressure control building can be implemented, thereby delaying the 66-inch redundant transmission main improvement from 21st and Zoo Boulevard to the WTP (Cheney supply); but since this transmission main also provides redundancy for the EBWF supply, the pressure control building is still required if the Cheney supply is conveyed through the existing southern 66-inch transmission main. Therefore, cost opinions for the pressure control building and the redundant 66-inch transmission main from 21st and Zoo Boulevard to the WTP are both included in the capital improvements plan. Since the East WTP Improvements project is currently under design and would be operational before implementing a redundant 66-inch transmission main from 21st and Zoo Boulevard to the WTP, the pressure control building has a higher priority with a hydraulic trigger functioning to maintain pressure less than 80 psi.

In the short term, capital improvements for the Cheney system have a higher priority until the East WTP Improvements are complete because the EBWF production capacity far exceeds the current groundwater-only treatment capability of the WTP; so enhancing the reliability of the Cheney system takes priority. After the East WTP Improvements are complete, the EBWF transmission mains are a higher priority than the Cheney 60-inch redundant transmission main, as this water supply source is more reliable under drought conditions. The EBWF is not only a more reliable supply, but is also more a robust supply source as it is comprised of over 60 individual wells as opposed to a single lake, intake and pump station like the Cheney system. Improvements can be re-prioritized if any item of infrastructure reaches a point where its condition degrades and continued use is an operational concern.

A summary of the prioritization and triggers for raw water transmission improvements is listed below:

Top priority:

- O Pressure control valve or structure implement before the East WTP Improvements project requires shifting the raw water blending location from upstream of the sleeve valves to downstream of the sleeve valves. The trigger for this improvement is to support Cheney system hydraulics and maintain operating pressure below 80 psi in the southern 66-inch transmission main.
- Note, this is designated a top, or higher priority, over replacing the southern 66-inch transmission main from 21st and Zoo Boulevard to the WTP transmission main based on cost and construction time.

- Low priority further prioritization requires a condition assessment:
 - o New 66-inch transmission from EBWF to 21st and Zoo Boulevard.
 - Note, existing transmission remains in service.
 - o New 66-inch transmission from 21st & Zoo Boulevard to the WTP.
 - The City should also consider replacing the existing transmission main to maintain full transmission redundancy for the EBWF and Cheney supplies; for clarity, this option requires two new transmission mains.
 - For the purposes of this master plan, only one new transmission main will be included in the CIP.
 - New 60-inch transmission from Cheney PS to 21st and Zoo Boulevard.
 - A 66-inch diameter can be considered if the hydraulic impact on the Cheney PS pumps and surge tank levels provides better operational value to the City and its operators.
 - Note, the existing transmission can remain offline and used when needed, for example under emergency conditions (main break) or for operational flexibility. This would provide transmission redundancy for the Cheney supply between the PS and 21st and Zoo Boulevard.

1.5.2 EBWF Supply Planning and Facility Needs

Water supply planning recommendations for the EBWF production and recharge goals align with the City's water supply plan with drought conditions and demand projections established in the Water Resources Plan. They also align with the 2014 recommendations included in the Enhanced ASR report (by Burns and McDonnell). The Water Resources Plan is based on an average day demand projection of 84 MGD by 2060 (or 72 MGD based on a 1 percent drought and with 35 percent conservation in effect); an average day demand of 84 MGD corresponds to a maximum day demand of approximately 160 MGD if extrapolated beyond the 2045 planning period. The capital improvements recommended to support a 160 MGD demand are discussed below.

1.5.2.1 Recharge Recovery Wells

Testing conducted by City staff in October 2016 indicated a maximum EBWF production capacity of 55 MGD. In a subsequent test, the maximum capacity of the EBWF 66-inch transmission main pipeline was estimated at approximately 79 MGD. An estimated 20 RRWs with a minimum production capacity of 20 MGD and goal of 30 MGD are needed to achieve an overall EBWF capacity of 70 MGD. This assumes

each well can produce 1,000 gpm. These wells would also provide additional locations to recharge the aquifer and spread recharge across the entire EBWF.

1.5.2.2 Bank Storage Wells

Based on the information and evaluation included in the Enhanced ASR Report, bank storage wells have the capability to provide approximately 3,700 MG/year of recharge water to the EBWF. Land availability at the time of the Enhanced ASR report assumed nine bank storage wells can provide up to an additional 15 MGD when flow in the Little Arkansas River is above baseflow. However, based on the ASR regulations, flow is not always available, as bank storage diversion is only permitted from the Little Arkansas River during above baseflow periods. Furthermore, the potential for elevated river levels above baseflow diminish during drought conditions.

Bank storage wells provide an added benefit when operated in conjunction with side stream storage (or an above base-flow holding reservoir). Side stream storage can be filled from the intake or bank storage wells and hold additional water during an above baseflow event to expand the volume of water for recharge. The ability to use bank storage wells to fill side stream storage at streamflow less than 65 cfs further extends recharge duration and increases the volume of water recharged. The existing ASR intake facility has physical withdrawal restrictions below 65 cfs; bank storage wells can capture additional diversions during above baseflow events.

1.5.2.3 Recharge Basins

Recharge basins provide operational flexibility during recharge events and provide a mechanism to recharge large volumes of water at a single site. They also provide additional locations to recharge water during start-up of the ASR Surface WTP before initiating recharge through RRWs. Detailed hydraulic and hydrogeological studies are required to evaluate each potential recharge basin site as not all sites are suitable for a recharge basin. For the purposes of this report, it is recommended that one recharge basin be installed for every 15 MGD of aquifer recharge wells. Based on the proposed 20 RRWs with a capacity of 20 to 30 MGD, two recharge basins are included in the CIP.

1.6 Conservation Efforts

In 1991 the City adopted its first Water Management and Conservation Plan and has been the driving force for water conservation. A number of water conservation measures have been implemented in some form by the City and include the following:

• Annual conservation goal of 0.35 percent.

 Water measurement and accounting: metering all source water and treated water components for normal consumption activity. The City has undergone a distribution system-wide meter replacement program with automatic meter reading technology; accurate customer billing is pivotal in lowering apparent losses, as defined by AWWA M36, and represents revenue that can be recovered and valued at the customer retail unit rate;

- Water pricing structure: an inclining block rate structure was implemented in 1993 for customers
 within City limits and additional charges on top of the rate structure for those outside City limits.
 Additionally, a flat water rate is available for large seasonal customers willing to reduce their
 consumption by 20 percent or 4 acre-feet, whichever is larger, and are assessed monetary fees if
 water usage is above the contracted amount;
- Rebate program from 2013 to 2016 for high efficient appliances including cloth washers, dishwashers, dual flush converter kits, irrigation smart controllers, low flow urinals, rain sensor shutoff, rain barrels, and toilets;
- Public education and awareness: the City's website offers guidance and information to save water on the customer end such as lawn watering recommendations, irrigation measures that conserve water, lawn care information, pool care, and links to a variety of other resources in this topic area. The website also informs customers on the City's internal conservation plans and supply management, most notably the Aquifer Storage and Recovery Project and efforts related to protecting Cheney Reservoir. The City conducted over 60 programs in 2016 at the WATER Center including presentations on water conservation;
 - WATER Center staff prepares water system characterization reports, reviews
 conservation plans, reviews retail volume applications and annual usage for compliance
 for retail volume contracts, and oversees the annual rebate program to name a few;
- The City has held a designated water efficiency coordinator position since 1990.
- Ongoing small mains replacement, particularly 2-inch galvanized pipe;
- Adopted a Drought/Water Shortage Contingency Plan that includes implementing voluntary and mandatory water efficiency measures;
- Wastewater reuse for the City's largest water user is anticipating a reduction in potable water consumption of 40 percent in 2017 and 70 percent in 2018 and beyond;
- Conjunctive use for the City's raw water supply sources; and
- Wholesale customer contracts include provisions to implement water efficiency plans that are, at a minimum, as comprehensive as the City's.

The City is also recommitting to the Kansas Water Office (KWO) guidelines, which is also supported by the Bureau of Reclamation and the Environmental Protection Agency, in areas of education efficiency practices, management efficiency practices, and regulatory efficiency practices.

The American Water Works Associations (AWWA) published a technical manual, M52 – Water Conservation Programs, detailing recommendations for conservation principles and practices in the municipal water industry. The City's conservation efforts are very comprehensive and include, in some form or fashion, those recommended by AWWA. Of note, the KWO guidelines discussed above are referenced in the AWWA M52 as exemplary practices for water conservation. A summary of the AWWA recommendations is listed below, and again, the City has or is currently performing all of these efforts in some form:

- Efficient utilization of supply sources;
- Integrated resource planning;
- Leak detection:
- Asset rehabilitation and replacement;
- Consumption monitoring with meter usage;
- Customer pricing tiered block rate structure;
- Public awareness and education; and
- Reuse water/wastewater.

The City has a solid water conservation program in place; however, there are several strategies that can be implemented over the next five years to evolve and enhance their current practices. Water conservation efforts recommended for the City, with the objective to reduce the average day demand and peak hour demands, includes the following in order of execution:

- Distribution system pressure management: evaluate and determine sub-pressure zone delineation potential to lower system pressure;
- AWWA M36 water audit: complete an annual water audit for the entire distribution system, for
 each pressure zone, and for each sub-pressure zone (if developed). This effort can be completed
 concurrently with distribution system pressure management tactics;
- Develop a leak detection program and response tactics for sub-pressure zone delineations.

1.7 Emergency Preparedness

1.7.1 Raw Water System

With the implementation of the Standby Power Generation project for the EBWF, the emergency power status of the EBWF is better than it has ever been based on recent historical WTP production needs; furthermore, there is no groundwater contribution requirement for the treatment process. The City can elect to purchase more portable generators as part of the project if a higher level of protection, with respect to groundwater production under loss of power conditions, is desired for drought and dry weather conditions.

Implementing more permanent generator locations is not recommended because the production advantage on an individual well basis is outweighed by added maintenance and escalating age of an asset that may only be required only a few times per year. Furthermore, well production can degrade over time if well and pump maintenance is not upheld; therefore, additional backup power in the EBWF is better served by portable generators that would enable the City to mobilize at well locations with higher production rates. With respect to the Cheney system, as water use approaches the projected maximum day demand of 160 MGD, backup power to support a firm capacity of 80 MGD at Cheney pump station is recommended; however, this demand is currently projected to occur in 2060, which is beyond the 2045 planning period in this master plan.

1.7.2 Water Treatment

There are two primary sources of backup power available to the WTP if both utility services above become unavailable and are briefly described below:

- No. 1: The switchgear gear lineups that provide the circuits to the WTP are currently backed-up by the Hess HSPS emergency generators. In the event of a utility outage on both Westar feeds, the generators will automatically provide power to Hess HSPS and the WTP.
- No. 2: A third feed from Westar is available if the primary two feeds and the emergency
 generators become unavailable. In order for the third feed to be used, the WTP must be manually
 isolated from the switchgear in the Hess HSPS generator building by opening the fused switches
 mentioned above, and then manually closing the emergency feed switches, thereby restoring
 power to the WTP.

The power supply arrangement and connection of the distribution equipment described above is based on review of several record drawings provided by the City and discussions with WTP staff. There does not appear to be a single document in the City's records that accurately depicts the current arrangement of the power distribution at Hess HSPS, the emergency generator facility, and the WTP combined. Therefore, a

study is recommended that establishes an accurate one-line diagram showing the arrangement and capacity of the transformers, generators, and distribution buses to better understand how the various power sources operate together in terms of primary and emergency power capability.

1.7.3 Water Distribution System

A current City project, titled Standby Power Generation (by others) and scheduled for construction in April 2017, includes backup power to support new pumps that replace BDP-2 (new at 3,000 gpm) and BDP-3 (new pump at 4,800 gpm) and support D1/M1 (3,475 gpm) for a total of 16.2 MGD and exceeds the peak hour plus fire flow demand for the Northeast pressure zone. The proposed pumping capacity with backup power also exceeds the year 2045 peak hour demand projection and fire flow requirement of 16.1 MGD. Therefore, backup power is not required at 37th Street BPS if the Northeast Tower is placed back in service and the control scheme for Webb Road PS changes as indicated previously in Section 11.5. However, if the Northeast Tower remains out of service, there may be interstitial demand conditions that require 37th Street BPS; therefore, emergency power at 37th Street BPS is recommended if the Northeast Tower remains out of service.

The standby power generation project discussed above also supports the Webb Road PS pumps serving the East pressure zone. The pumping capacity with backup power as indicated in construction drawings, is 37.0 MGD, and exceeds the peak hour plus fire flow requirement. The projected 2045 peak hour plus fire flow requirement is approximately 38.5 MGD; therefore, a recommendation to install additional backup power at the Southeast BPS could be made, but given the volatility of growth in the East pressure zone since 2003, additional backup power at the Southeast BPS should be delayed until development occurs and water demands escalate. The Southeast BPS is equipped with a manual transfer switch to dock a temporary or mobile emergency power generator.

If West Maple BPS loses power, then, under current maximum day and peak hour demands, the model indicates adequate flow and pressure (greater than 25 psi) can be provided while repairs are made. Since fire flow is provided by Hess pressure zone, a fire flow condition with a loss of power at West Maple BPS is not a basis fire adding backup power; the existing West Maple BPS is not sized to deliver fire flow. The addition of backup power should be revisited as development occurs and water demands increase above the projections indicated for this area.

The Hess HSPS pumping capacity with backup power is approximately 97.2 MGD from 3 pumps and can deliver the 2015 peak hour demand (81.0 MGD) plus fire flow requirement (10.8 MGD (7,000 gpm)) which totals 91.8 MGD for Hess pressure zone only (this does not include the East pressure zone). This

emergency condition represents loss of power at Hess HSPS with no interruption to the treatment process treating and supplying the reservoir system. This review summarizes the effective pumping capacity for Hess pressure zone and provides the City a quantitative method to size capital improvements for additional backup power to cover other operational goals for emergency service as determined by the City. Some examples of potential operational goals are listed below:

- Providing backup power for the Hess pressure zone projected 2045 peak hour plus fire flow demand of 122 MGD for four (4) pumps at Hess HSPS with a combined pumping capacity estimated at 122.4 MGD (at 264 ft of pump head).
 - The caveat with this operational goal (example only) is the treatment capacity of the WTP. The emergency conditions assume the WTP can treat and supply the Hess Reservoir system at a rate equal to what can be pumped out by Hess HSPS. The rated treatment capacity of the Main WTP is 160 MGD, but the operational capacity is less and potentially limited by hydraulic bottlenecks, backwashing capability, and/or filter loading; therefore, if the operational treatment capacity is less than Hess HSPS pumping capacity, then the recommendation to increase backup power has a diminishing return until the operational treatment capacity is increased above 122.4 MGD.
 - Note, since the East pressure zone has no storage and is supplied by the Hess pressure zone, sizing backup power to support 122 MGD will be shared with East pressure zone demands.
- Providing some portion or all of the East pressure zone demand conditions. For example, assuming the 2015 peak hour in the Hess (81.0 MGD) and East (24.4 MGD) pressure zones occurs simultaneously, plus the fire flow requirement of Hess pressure zone at 10.8 MGD, requires backup power to support a total of 116.1 MGD.
- Note, fire protection for customers with high requirements up to 7,000 gpm, or a portion thereof, can be the responsibility of the customer; therefore, the City should develop a comprehensive list of customers with high fire flow requirements and respective protection responsibilities. This could affect future capital improvement recommendations for backup power. For clarity, even if the full fire flow requirement, in terms of pumping, is not required, the equivalent fire protection volume in Hess reservoir system should be maintained.
- Also of note, the primary power and backup power study discussed and recommended in Section
 1.7.2 should be completed before capital improvements for additional backup power at Hess
 HSPS are evaluated further. Additionally, it is reasonable for the City to reduce recreational
 water use and implement water use restrictions for the customer population in an emergency
 situation that temporarily terminates primary power from Westar at Hess HSPS.

1.8 Capital Improvements Plan

Cost opinions are provided for capital improvements in today's dollars for the raw water, water treatment, and distribution systems. There are three capital improvement plan options and include the Base Option, Option No. 1, and Option No. 2. The Base Option does not include a new WTP and Option Nos. 1 and 2 include the new NWTP, but with different treated water delivery mechanisms. The opinions of probable cost for each option is grouped as follows and summarized in Tables 1.3, 1.4, and 1.5:

- Base Option = \$387 million
- Base Option plus Option No. 1 = \$618 million
 - Option No. 1 has dedicated treated water transmission from the NWTP to Hess Reservoir system for distribution.
 - If RO is not required for the NWTP, then \$17.3 million can be deducted from the cost above.
- Base Option plus Option No. 2 = \$599 million
 - Option No. 2 has direct service to Hess pressure zone from the NWTP and associated transmission improvements to support this in the distribution system.
 - o If RO is not required for the NWTP, then \$17.3 million can be deducted from the cost above.

These order-of-magnitude cost opinions prepared by Burns & McDonnell relating to costs, quantities, demand or pricing (including, but not limited to, property costs, construction, operations or maintenance costs, and/or energy or commodity demand and pricing), are opinions based on Burns & McDonnell's experience, qualifications, judgment, and information from vendors and published sources such as Means. Burns & McDonnell has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's means and methods, unavoidable delays, construction contractor's method of pricing, demand or usage, population demographics, market conditions, changes in technology, government regulations and laws, and other economic or political factors affecting such opinions. The City of Wichita acknowledges that actual results may vary significantly from the representations and opinions herein, and nothing herein shall be construed as a guarantee or warranty of conclusions, results, or cost opinions. Burns & McDonnell makes no guarantee or warranty (actual or implied) that actual rates, demand, pricing, costs, performance, schedules, quantities, technology, and related items will not vary from the opinions contained in the estimates, projections, results, or other statements or opinions prepared by Burns & McDonnell. The construction cost index for Kansas City, August 2016, is 11371.00.

Table 1.3
Cost Opinion Summary: Base Option

System	2017	2018	2020	2025	2030	2035	2045	System Subtotal	
Distribution	\$123,000		\$8,600,000			\$1,560,000	\$30,040,000	\$40,300,000	
Treatment		\$12,150,000	\$15,810,000					\$28,000,000	
Raw Water ¹		\$3,200,000		\$163,290,000	\$151,790,000			\$318,300,000	
Planning Period Subtotal	\$123,000	\$15,350,000	\$24,410,000	\$163,290,000	\$151,790,000	\$1,560,000	\$30,040,000		
Total (all systems & all planning periods)									

Notes:

1. Trigger year for raw linear improvements portion of the capital cost summary is contingent upon a condition assessment; years 2025 and 2030 are placeholders.

Table 1.4
Cost Opinion Summary: Base Option with Option No. 1

System	2017	2018	2020	2025	2030	2035	2045	System Subtotal	
Distribution	\$123,000		\$8,600,000			\$1,560,000	\$30,040,000	\$40,300,000	
Treatment ¹		\$12,150,000	\$15,810,000			\$231,200,000		\$259,200,000	
Raw Water ²		\$3,200,000		\$163,290,000	\$151,790,000	-		\$318,300,000	
Planning Period Subtotal	\$123,000	\$15,350,000	\$24,410,000	\$163,290,000	\$151,790,000	\$232,760,000	\$30,040,000		
Total (all systems & all planning periods) \$617,800,000									

Notes:

- 1. If RO is not required for the NWTP, then \$17.3 million can be deducted from the cost above.
- 2. Trigger year for raw linear improvements portion of the capital cost summary is contingent upon a condition assessment; years 2025 and 2030 are placeholders.

Table 1.5
Cost Opinion Summary: Base Option with Option No. 2

, , , , , , , , , , , , , , , , , , , ,											
System	2017	2018	2020	2025	2030	2035	2045	System Subtotal			
Distribution	\$123,000		\$8,600,000			\$27,230,000	\$30,040,000	\$66,000,000			
Treatment ¹		\$12,150,000	\$15,810,000			\$186,370,000		\$214,300,000			
Raw Water ²		\$3,200,000		\$163,290,000	\$151,790,000			\$318,300,000			
Planning Period Subtotal	\$123,000	\$15,350,000	\$24,410,000	\$163,290,000	\$151,790,000	\$213,600,000	\$30,040,000				
Total (all systems & all planning periods) \$598,600,000											

Notes:

- 1. If RO is not required for the NWTP, then \$17.3 million can be deducted from the cost above.
- 2. Trigger year for raw linear improvements portion of the capital cost summary is contingent upon a condition assessment; years 2025 and 2030 are placeholders.

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1.8.1 Economic Evaluations

Economic evaluations include a present worth analysis to compare the present value of Option No. 1 and Option No. 2 and determining the operation and maintenance (O&M) cost to produce water for each option. These options include a new NWTP with the following variations:

- Option No. 1 includes dedicated finished water transmission from a new NWTP to the finished water reservoir system at the existing WTP for high service pumping to the distribution system.
- Option No. 2 includes finished water with direct service to the distribution system from a new NWTP.

The present worth analysis for Option No. 1 is shown in Table 1.6 in results in a present value of \$197,286,000. The present worth analysis for Option No. 2 is shown in Table 1.7 results in a present value of \$183,899,000. By the 2045 planning period the O&M cost of water for Option No. 1 and Option No. 2 is \$1.74/1,000 gallons and \$1.70/1,000 gallons respectively.

1.8.2 Non-economic Evaluations

Non-economic considerations for redundancy driven improvements associated with the raw water system and water treatment facilities are listed below:

- Raw Water Transmission: To Be Decided (TBD) (year)-EBWF 66" Transmission-R-1, TBD(year)-Cheney 60" & 66" Transmission-R-2
 - Advantages:
 - The existing transmission main could be removed from service for maintenance or repair without impacting surface water availability.
 - Water supply will be unavailable if a main break occurs until repairs can be made.
 - Redundant transmission can mitigate difficulties in procuring pipe sections, fittings, and valves of this size.
 - Issues with mobilization delays due to the limited number of qualified contractors to perform emergency work is diminished with redundant transmission.
 - Year-EBWF 66" Transmission-R-1: provides redundant transmission capacity from the EBWF to 21st & Zoo Boulevard. Timing of installation should be based on a condition assessments to be completed as a future project.
 - Year-60" & 66" Cheney Transmission-R-2: when the East WTP Improvements
 project is complete and raw water is blended downstream of the sleeve valves at

Table 1.6
New Northwest WTP Present Worth Analysis - Option No. 1

	Capital Cost ¹		Operation and Maintenance Costs ²									Average Day	00046-4-4
Year	Treatment	Transmission	NWTP Transfer			Membrane &	Other				Present Value	Average Day Demand ⁴	O&M Cost of Water
Teal	2035-NWTP-R-1	2035-FWT-R-2	Pumping Energy ⁵	RO Energy ⁶	Chemical ⁷	Cartridge Filter Replacement	Replacement ⁸	Wages ⁹	Total O&M	Value ³	Cummulation	(MGD)	(\$/1,000 gal)
2016													
2017													
2018													
2019													
2020													
2021													
2022													
2023													
2024													
2025													
2026													
2027													
2028													
2029													
2030													
2031													
2032													
2033													
2034													
2035	\$358,297,000	\$86,174,000	\$208,000	\$4,307,000	\$2,467,000	\$0	\$0	\$4,876,000	\$11,858,000	\$150,823,000	\$150,823,000	35.15	\$0.92
2036			\$217,000	\$4,479,000	\$2,556,000	\$1,990,000	\$2,278,000	\$5,022,000	\$16,542,000	\$5,158,000	\$155,981,000	35.19	\$1.29
2037			\$226,000	\$4,658,000	\$2,648,000	\$2,059,000	\$2,358,000	\$5,173,000	\$17,122,000	\$5,037,000	\$161,018,000	35.23	\$1.33
2038			\$235,000	\$4,845,000	\$2,744,000	\$2,132,000	\$2,441,000	\$5,328,000	\$17,725,000	\$4,919,000	\$165,937,000	35.27	\$1.38
2039			\$245,000	\$5,038,000	\$2,843,000	\$2,206,000	\$2,526,000	\$5,488,000	\$18,346,000	\$4,803,000	\$170,740,000	35.31	\$1.42
2040			\$255,000	\$5,240,000	\$2,946,000	\$2,283,000	\$2,614,000	\$5,652,000	\$18,990,000	\$4,690,000	\$175,430,000	35.35	\$1.47
2041			\$266,000	\$5,449,000	\$3,053,000	\$2,363,000	\$2,706,000	\$5,822,000	\$19,659,000	\$4,581,000	\$180,011,000	35.39	\$1.52
2042			\$277,000	\$5,667,000	\$3,163,000	\$2,446,000	\$2,801,000	\$5,997,000	\$20,351,000	\$4,473,000	\$184,484,000	35.43	\$1.57
2043			\$288,000	\$5,894,000	\$3,278,000	\$2,532,000	\$2,899,000	\$6,177,000	\$21,068,000	\$4,369,000	\$188,853,000	35.47	\$1.63
2044			\$300,000	\$6,130,000	\$3,396,000	\$2,620,000	\$3,000,000	\$6,362,000	\$21,808,000	\$4,266,000	\$193,119,000	35.51	\$1.68
2045			\$312,000	\$6,375,000	\$3,519,000	\$2,712,000	\$3,105,000	\$6,553,000	\$22,576,000	\$4,167,000	\$197,286,000	35.55	\$1.74
Totals	\$358,297,000	\$86,174,000		1	-		-			\$197,286,000		-	-

Notes:

- 1. Capital cost inflated at 3.5 percent.
- 2. Energy inflated at 4.0 percent; chemical and equipment replacement inflated at 3.5 percent; plant personnel wages inflated at 3.0 percent.
- 3. Present value with fixed interest at 6.0 percent
- 4. Average day demand is half of the demand projection; assumes 50 percent of the average day demand is treated by the NWTP and 50% is treated by the existing WTP.
- 5. Energy costs for water transfer from NWTP to Hess reservoir system for distribution system pumping; this does not represent Hess HSPS energy costs.
- 6. RO energy for 13.3 MGD of RO treatment.
- 7. Chemical is based on the highest 4-year chemical costs for the existing WTP which occurred in 2015 at \$0.10/1,000 gallons.
- 8. Other replacement is estimated at 2 percent of the non-membrane and non-filtration capital cost without markups.
- 9. Wages are based on inflated 2015 expenditures for existing water treatment and pumping personnel less the wages for a superintendent, lab director, maintenance supervisor, and clerk

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Table 1.7
New Northwest WTP Present Worth Analysis - Option No. 2

	Capital Cost ¹			Operation and Maintenance Costs ²								Average Day	0014 0
Year	Treatment Distribution 2035-NWTP-R-1 2035-Hess-Option 2-H-1		Pumping Energy Savings ⁵	RO Energy ⁶	Chemical ⁷	Membrane & Cartridge Filter Replacement	Other Replacement ⁸	Wages ⁹	Total O&M	Total Present Value ³	Present Value Cummulation	Average Day Demand ⁴ (MGD)	O&M Cost of Water (\$/1,000 gal)
2016													
2017													
2018													
2019													
2020													
2021													
2022													
2023													
2024													
2025													
2026													
2027													
2028				-									
2029				-									
2030													
2031				-									
2032				-									
2033				-									
2034				-									
2035	\$358,297,000	\$49,351,000	-\$157,000	\$4,307,000	\$2,467,000	\$0	\$0	\$4,876,000	\$11,493,000	\$138,532,000	\$138,532,000	35.15	\$0.90
2036			-\$163,000	\$4,479,000	\$2,556,000	\$1,990,000	\$2,278,000	\$5,022,000	\$16,162,000	\$5,039,000	\$143,571,000	35.19	\$1.26
2037			-\$170,000	\$4,658,000	\$2,648,000	\$2,059,000	\$2,358,000	\$5,173,000	\$16,726,000	\$4,920,000	\$148,491,000	35.23	\$1.30
2038			-\$177,000	\$4,845,000	\$2,744,000	\$2,132,000	\$2,441,000	\$5,328,000	\$17,313,000	\$4,804,000	\$153,295,000	35.27	\$1.34
2039			-\$184,000	\$5,038,000	\$2,843,000	\$2,206,000	\$2,526,000	\$5,488,000	\$17,917,000	\$4,691,000	\$157,986,000	35.31	\$1.39
2040			-\$192,000	\$5,240,000	\$2,946,000	\$2,283,000	\$2,614,000	\$5,652,000	\$18,543,000	\$4,580,000	\$162,566,000	35.35	\$1.44
2041			-\$200,000	\$5,449,000	\$3,053,000	\$2,363,000	\$2,706,000	\$5,822,000	\$19,193,000	\$4,472,000	\$167,038,000	35.39	\$1.49
2042			-\$208,000	\$5,667,000	\$3,163,000	\$2,446,000	\$2,801,000	\$5,997,000	\$19,866,000	\$4,367,000	\$171,405,000	35.43	\$1.54
2043			-\$216,000	\$5,894,000	\$3,278,000	\$2,532,000	\$2,899,000	\$6,177,000	\$20,564,000	\$4,264,000	\$175,669,000	35.47	\$1.59
2044			-\$225,000	\$6,130,000	\$3,396,000	\$2,620,000	\$3,000,000	\$6,362,000	\$21,283,000	\$4,164,000	\$179,833,000	35.51	\$1.64
2045			-\$235,000	\$6,375,000	\$3,519,000	\$2,712,000	\$3,105,000	\$6,553,000	\$22,029,000	\$4,066,000	\$183,899,000	35.55	\$1.70
Totals	\$358,297,000	\$49,351,000		1						\$183,899,000			

Notes:

- 1. Capital cost inflated at 3.5 percent.
- 2. Energy inflated at 4.0 percent; chemical and equipment replacement inflated at 3.5 percent; plant personnel wages inflated at 3.0 percent.
- 3. Present value with fixed interest at 6.0 percent
- 4. Average day demand is half of the demand projection; assumes 50 percent of the average day demand is treated by the NWTP and 50% is treated by the existing WTP.
- 5. Pumping the total average day demand from two locations (new NWTP and existing WTP) requires less pressure than pumping the total demand from one location (i.e. Option No. 1).
- 6. RO energy for 13.3 MGD of RO treatment.
- 7. Chemical is based on the highest 4-year chemical costs for the existing WTP which occurred in 2015 at \$0.10/1,000 gallons
- 8. Other replacement is estimated at 2 percent of the non-membrane and non-filtration capital cost without markups
- 9. Wages are based on inflated 2015 expenditures for existing water treatment and pumping personnel less the wages for a superintendent, lab director, maintenance supervisor, and clerk

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the WTP then, under static conditions, the maximum pressure at the WTP on the existing Cheney line can reach 108 psi – which exceeds the design operating pressure of 80 psi. This improvement will remove operational concerns associated with pressure.

o Disadvantages:

- Land acquisition and easements.
- Constructability in high traffic and densely populated residential and commercial areas.
- Increasing asset inventory requires additional maintenance, i.e. air release valves, in-line valves, cathodic protection if required, etc.

Raw Water Facilities

- o Bank Storage Wells (2020-Bank Storage Wells-RC-1)
 - Advantages:
 - Capture above base flow river conditions (below 65 cfs) that the ASR intake facility cannot.
 - Provides a diversion mechanism for side stream storage.
 - Provide peaking assistance with respect to raw water supply needs.
 - Disadvantages:
 - Production cannot be relied on when flows are at or below baseflow in the river.
 - Above base flow events are less likely to occur during drought periods.
- o RRWs (2022-Recharge Recovery Wells-RC-2)
 - Advantages:
 - Increase production capacity from EBWF.
 - Increase recharge capacity into EBWF.
 - Provide more opportunity to evenly distribute recharge throughout the well field to prevent mounding.
 - More production options available, on an individual well basis, when existing wells are temporarily out of service for maintenance.
 - Needed to meet the long-term water supply needs if maximum day demands approach 160 MGD (estimated in 2060 in the City's Water Resources Plan), assuming the capacity of Cheney PS and transmission main is restored to 80 MGD.
 - Disadvantages:

- Increasing asset inventory requires additional maintenance.
- o Recharge Basins (2022-Recharge Basins-RC-3)
 - Advantages:
 - Provide operational flexibility during recharge events and for aquifer recharge.
 - Disadvantages:
 - Increasing asset inventory requires additional maintenance.
- Water Treatment
 - On-site Sodium Hypochlorite Generation (2020-On-Site Sodium Hypochlorite Generation-Trigger-1)
 - Advantages:
 - Safety of the disinfection application is increased.
 - Disinfectant storage for liquid is safer than gas for the amount required.
 - Removes risk associated with chlorine storage (gas) leak.
 - Reduces hazardous chemical storage requirements.
 - Disadvantages:
 - None.
 - O New 80-MGD NWTP (Option No.'s 1 and 2)
 - Advantages:
 - Provides total treatment redundancy of 160 MGD.
 - Continue delivering up to 80 MGD with loss of the existing treatment process upstream of the chlorine contact basin.
 - Disadvantages:
 - Increasing the system treatment capacity with a new NWTP will increase maintenance needs and operational complexity.
 - RO concentrate disposal permitting associated with deep injection wells if selected as the disposal mechanism.
 - o Option No. 1 (dedicated transmission to Hess Reservoir system)
 - Advantages:
 - Single delivery point for distribution system is maintained.
 - No operational changes with respect to high service pumping.
 - No changes with respect to distribution system monitoring, analysis, or regulatory requirements.

- Disadvantages:
 - Transmission constructability in residential areas with dense population.
 - Does not provide high service pumping redundancy for the distribution system.
 - Transmission break would effectively take the NWTP offline until corrected.
 - Can increase water age and reduce chlorine residual before entering the distribution system; may require additional disinfectant application in Hess reservoir system.
- Option No. 2 (direct pumping/service to distribution system from NWTP)
 - Advantages:
 - Improve operational flexibility for water delivery to the distribution system.
 - High service pumping from two locations is anticipated to lower the average operating pressure in Hess pressure zone.
 - Increase the total and effective storage capacity for the distribution system and/or remove some portion of the storage in Hess Reservoir system in a manner that improves water age and turnover in reservoirs that have historically low chlorine residuals.
 - Continue providing water to customers during emergency situations if Hess HSPS is out of service.
 - Potential to retire a portion of the existing pumps at Hess HSPS.
 - Improve managing the control pressure of 92 psi at Central and Main.
 - Disadvantages:
 - Complexity of distribution system operation increases; but, will also improve operational flexibility.
 - Additional regulatory sampling requirements in the distribution system.

1.8.3 Financial Analysis

1.8.4 Approach and Initial Findings

The primary goal of this financial assessment is to evaluate rate stability and debt service coverage implications with the proposed capital improvement plans to achieve the following objectives:

1-37

• Evaluate current usage levels and prepare revenue forecast.

- Project capital flow of funds.
- Project operating revenue requirements.
- Review and finalize operating cash flow.

Our analytic approach includes the development of cash flow models that test the ability of revenues under existing rates to meet future operating and capital requirements of the system. For the master plan, this includes a forecast period beginning fiscal year (FY) 2016 through FY 2045. The sufficiency of revenues under existing rates was evaluated for three scenarios, including the base case, and two options (Option 1 and Option 2) that include the design and construction of a new water treatment plant. Table 1.8 summarizes findings regarding revenue sufficiency.

Table 1.8 - Revenue Sufficiency Findings

			<u> </u>	
	2017 - 2045 Cumulative %			
Scenario	Increase	Total CIP	Total Debt Funded	Total Cash Funded
Base Case	6.12%	\$517,963,500	\$205,500,000	\$312,463,500
Option 1	64.49%	\$898,848,800	\$639,000,000	\$259,848,800
Option 2	61.19%	\$867,342,900	\$613,000,000	\$254,342,900

The cumulative increase shown in the second column of Table 1.8 signals that revenue under existing rates is not sufficient to adequately fund future revenue requirements. In all three scenarios, revenue increases are indicated to be necessary. For the Base Case, a total revenue increase through 2045 amounts to about 6 percent. Option 1 and Option 2 are indicated to need higher levels of total revenue increases through 2045, amounting to about 64 percent for Option 1 and 61 percent for Option 2.

The most significant funding requirement is the implementation of the capital improvements identified in the master plan scenarios. These improvements, inflated from current dollars used in the master plan scenarios, total about \$518 million for the Base Case, and nearly \$899 million for Option 1 and \$867 million for Option 2. A substantial portion of the capital improvement program for each scenario is anticipated to be funded from debt issuance. Additional operating cost has been added for the new Northwest Water Treatment Plant beginning in 2035 in Option 1 and Option 2.

Table 1.8 indicates cumulative revenue increases to range from about 6 percent to about 65 percent, depending on scenario. The annual revenue adjustments are illustrated in Figure 1.1 below. Depending on the scenario, annual increase range from a low of 0 percent to a high of 9 percent.

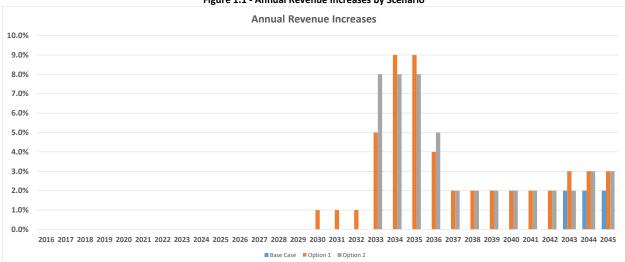


Figure 1.1 - Annual Revenue Increases by Scenario

No increase is indicated to be necessary under any scenario until FY 2030. The reason this is possible is that demand is projected to return to a level higher than experienced in the last four years due to prevailing climate conditions. For instance, FY 2016 water rate revenues amounted to approximately \$75 million, while FY 2017 water rate revenues are forecasted to be nearly \$90 million, an increase that is primarily driven by an assumed return to more normal demand. This increase provides additional cash that can be used to fund capital projects and inflationary increases in operation and maintenance expenses.

1.8.5 Key Assumptions

Cash flow projections involve reliance upon assumptions regarding future conditions. Key assumptions used in this analysis include the following:

- Demand forecast/water production forecast. Forecasted demand is consistent with demand anticipated in the master planning projections. Average day demand is expected to increase from 50.8 MGD in FY 2016 to 66.9 MGD in FY 2020, with further increases to 70.3 MGD in FY 2035 and then to 71.1 MGD in FY 2045. Demand is estimated to increase linearly between all milestone projections.
- Operation and maintenance expenses. Budgeted operation and maintenance expense (O&M) is reflected for fiscal years 2017 and 2018. General inflation of 3.4 percent per year is assumed for

O&M in subsequent years. Additionally, Options 1 and 2 have incremental O&M expenses beginning in FY 2035 related to the operation of the new water treatment plant.

- Capital Improvement Plan. Capital improvements forecasted through the study period reflect the master planning projects cited within this report, which are based in current year dollars. Capital improvements are inflated at 3.0 percent annually.
- **Debt issuance terms.** Debt issuance is anticipated to be necessary for all scenarios. All debt is assumed to be in the form of water revenue bonds with a 20-year term. Average interest rates are assumed to be 5.0 percent for debt issued in 2017, increasing to 5.5 percent by 2019 and remaining at that level throughout the remainder of the study period. Debt issuance costs are assumed to be 2 percent of gross bond proceeds.
- Fund Balances and Targets. The beginning Operating Balance was provided by the City as of the end of FY 2015. The minimum target for the operating fund is at least 60 days of O&M, which is achieved in all scenarios. Monies in excess of the minimum target are made available to fund capital projects. Capital fund balances are set to be at least 25 percent of the following year's capital improvement plan.
- **Debt Service Coverage Targets**. The utility measures debt service coverage on revenue bonds, and all debt. For cash flow planning purposes, the minimum annual debt service coverage ratio is 1.20x on all debt including general obligation bonds. As a practical matter, most scenarios achieve minimum forecasted debt service coverage of 1.50x on all debt. During the course of the study period, the existing debt service fully amortizes. By the end of the study period, only the proposed revenue bonds are anticipated to be outstanding.

1.8.6 Capital Improvement Funding

In the Base Case, Figure 1.1 indicates no revenue increases are anticipated until FY 2043 which is primarily a function of increased demand and revenue throughout the forecast period. Figure 1.2 below summarizes the Base Case capital improvement plan. Total improvements per year are represented by the blue line. The inflated Capital Improvement Plan (CIP) peaks at approximately \$74 million in 2028, falling to \$0 by 2031.

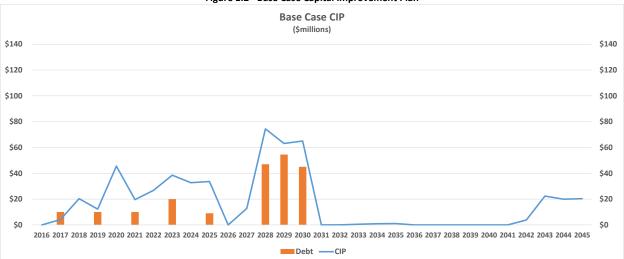


Figure 1.2 - Base Case Capital Improvement Plan

Debt issuance is represented by the orange bars in Figure 1.2. The amount of cash used to finance the CIP is represented by the distance between the bars and the CIP line. Figure 1.2 indicates that through FY 2028, much of the CIP can be financed with cash coming from existing balances and future cash flows. More substantial debt issuance is anticipated during FY 2028 through 2030. Remaining CIP projects forecasted in FY 2042 through FY 2045 are projected to be completely cash funded.

Figure 1.3 summarizes the CIP and funding plan for Option 1. Similar to the Base Case, initial CIP is anticipated to be funded with both cash and debt. The Option 1 CIP peaks in FY 2033 to FY 2035 due to the construction of the new water treatment plant. The inflated CIP totals approximately \$369 million during this three year period, and much of that requirement is expected to be debt financed. In FY 2036, the Option 1 CIP drops to \$0 until FY 2042 when additional growth related projects are anticipated.

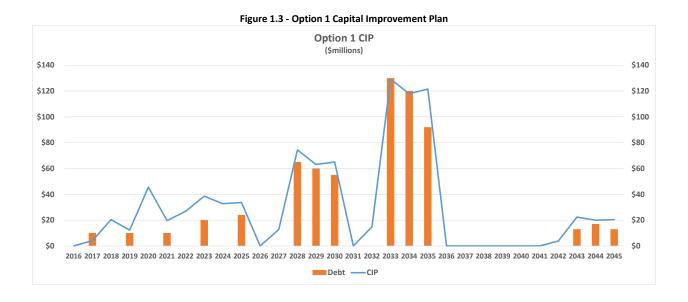
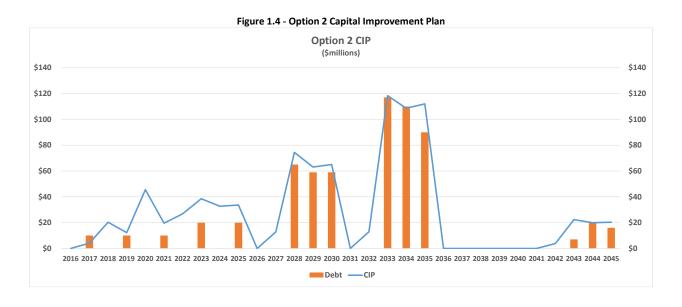


Figure 1.4 summarizes the CIP and funding plan for Option 2. Similar to the Base Case, initial CIP is anticipated to be funded with both cash and debt. As with Option 1, the capital plan peaks in FY 2033 to FY 2035 due to the construction of the new water treatment plant. In Option 2, the inflated CIP is slightly lower than Option 1 at approximately \$339 million during this three year period. As in the previous scenario, the Option 2 CIP drops to \$0 in FY 2036 until FY 2042 when additional growth related projects are identified.

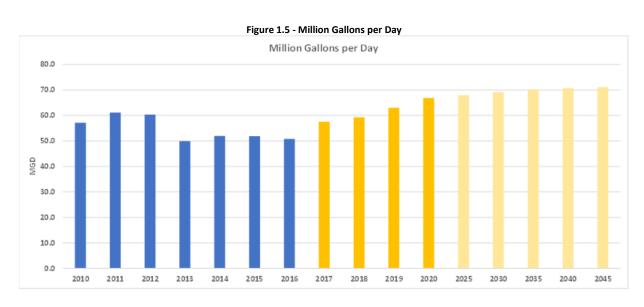


1.8.7 Important Caveats

It is important to recognize some caveats regarding the financial analysis performed for the master plan scenarios.

- 1. Capital improvement plans are limited to only the projects identified in the master plan. To the extent other projects or initiatives are underway or planned, especially within the next 5-10 years, such projects are not included unless they are reflected in the master plans. This approach provides a basis for comparing master plan scenarios, but the indicated revenue increases do not provide funding for projects or initiatives outside the proposed master plan capital improvements.
- 2. It is assumed that any existing water capital balance available at the beginning of FY 2016 is committed to other water utility projects and is not available for use in this master plan assessment. In doing so, all master plan projects are assumed to be funded from either future cash flow or issuance of debt.
- 3. Water utility rate revenues have ranged from approximately \$63 million to \$75 million per year from 2013 to 2016, a period of time with unusually higher than typical precipitation. During this time, average day water production has been about 51 mgd. The FY 2017 water utility budget anticipates water rate revenues of approximately \$90 million, with the expectation that water demand is more consistent with average climate conditions and historic usage levels. Should water demand fail to achieve forecasted levels, the need for additional revenue increases beyond those indicated for each scenario are anticipated.

Figure 1.5 shows the recent history and projections of water average demand through FY 2045. Annual forecasts are shown in Figure 14.5 for FY 2017 through FY 2020. Beyond FY 2020, Figure 1.5 shows



five year intervals. Annual cash flow modeling assumes linear increases in demand from year to year to achieve the indicated milestones.

The increase in demand shown from FY 2016 to FY 2017 is the anticipated result of a return to generally normal climate conditions and demand levels. FY 2018 through FY 2020 includes continued normal climate conditions and additional growth as developed in the master plan.

The increased demand correlates to increased revenue. Figure 1.6 shows the historical and projected revenue over the same time intervals as Figure 1.5. Rate revenue is anticipated to increase from about \$75 million in FY 2016 to about \$90 million in FY 2017, consistent with utility budgets. This increase provides substantial cash flow which is used to fund capital projects.

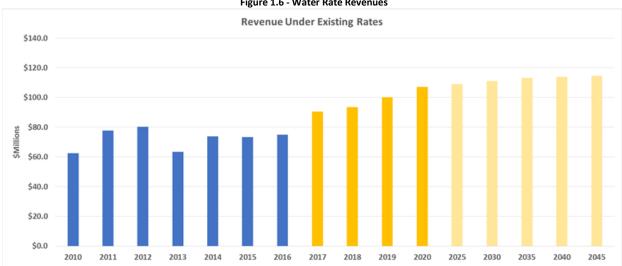


Figure 1.6 - Water Rate Revenues

In our analysis of financial impacts associated with capital plans, the assumption that demand returns to a more "normal" level in 2017 and is sustained through the study period is a material assumption. Absent the cash flow created by the assumed increase in demand, revenue increases required to fund the proposed capital plans would be substantially higher.

2.0 INTRODUCTION

2.1 PURPOSE

The purpose of the water master plan (WMP) is to update existing hydraulic models of the raw water and potable water distribution systems and use them to evaluate current and anticipated future conditions to determine required capital improvements. The raw water model includes Cheney Pump Station, Equus Beds Well Field (EBWF), Bentley Wells, local wells, and associated transmission and yard piping. The water distribution system model includes retail and wholesale customer demands, Hess High Service Pump Station (HSPS), Webb Road Pump Station (PS), 37th Street Booster Pump Station (BPS), Southeast BPS, and Maple BPS, Woodlawn and Roosevelt elevated tanks, and the distribution system network. A stand-alone model for the Hess reservoir system is developed to evaluate water age and potential operating schemes, from a volume requirement basis, for seasonal water demands.

Water distribution system improvements are prioritized and classified as hydraulic, development (future growth), and fire flow. As improvements are scheduled for engineering and construction, final design-level modeling should be conducted to confirm proposed operating conditions and to confirm the actual operating conditions in the distribution system are consistent with the operating conditions evaluated in this report and the hydraulic model.

2.2 SCOPE

Major tasks in the scope include a water demand projections review and update, raw water and distribution system field testing for model calibration, model development, hydraulic analysis of current and future water demand scenarios for capital improvements planning, and final report of the project findings. A comprehensive description for each task in the scope is listed below:

- Water Supply and Demand Evaluation
 - Review existing information pertinent to water demand including the 2005 Water Master Plan, 2013 Water Demand Assessment, and the 2015 Water Resources Plan.
 - Compare current water usage and population with existing information from the sources above and adjust water demand projections as necessary. Review current large users and summarize historical metered water usage.
 - Review existing water supplies and their anticipated remaining useful life as part of the CITY's water portfolio.
- Water System Master Planning for Future Planning Periods (future growth)

 Review the 2013 Water Demand Assessment and Metropolitan Area Planning Department (MAPD) growth areas with CITY and determine the area, service implementation year, rate of development, and customer classification.

- Project customers and water demands in new future growth areas and fill-in growth within existing areas for each planning period; summarize demand projections for growth areas by customer class.
- Planning periods for water system master planning and hydraulic modeling include the current year and future years 2020, 2035, and 2045.
- Evaluate demand conditions for each planning period to determine the adequacy of
 existing water system and determine necessary improvements for distribution piping,
 transmission, pumping, storage, fire flow, pressure zone adequacy, and future growth
 piping to support the demand projections. Review existing system results and proposed
 improvements with CITY.
- Additional Modeling Tasks:
 - Review the current pressure zone delineation and determine what, if any, improvements are necessary to support future land use planning.
 - Operation of the Northeast Pressure Zone and Northeast Tower.
 - Southeast Booster Pump Station controls.

Water Facilities Evaluation:

- Water Supply Facilities:
 - Review the existing water supply capacities and planned additions are adequate to meet the water demand projections through the year 2045.
 - If necessary, determine limiting factor(s) associated with a water supply deficit and potential solutions for each planning period.
- Water Treatment Facilities:
 - Review the existing water treatment capacity and the need for any future treatment facilities to meet the water demand projections through the year 2045.
 - If necessary, determine the limiting factor(s) associated with a water treatment capacity deficit and potential solutions for each planning period.
- Water Distribution Facilities:
 - Review existing capacities of water distribution system pumping and storage facilities and the need for any future pump(s) or pumping facilities to meet the water demand projections through the year 2045.

 If necessary, determine the limiting factor(s) associated with a pumping deficit and potential solutions for each planning period.

• Regulatory Review

- o Identify and summarize the applicable regulatory requirements from Kansas Department of Health and Environment (KDHE) and the Environmental Protection Agency (EPA).
- Summarize possible changes to regulatory requirements and the impact to existing treatment facilities and potential future expansions.
- Establish finished water quality goals and evaluate potential improvements to water treatment facilities and operations required to maintain regulatory compliance.
- Develop regulatory evaluation in report.
- Water Distribution Model of Existing System
 - Review and update existing model:
 - Model software review and selection.
 - Update the previous model with the CITY's current water system GIS.
 - Incorporate calibration data from previous model into the new model.
 - Develop a stand-alone model for Hess reservoirs and piping system. Evaluate water age and mixing system alternatives and/or operational strategies to lower water age.
 - Incorporate all pipes greater than or equal to 8-inches in diameter and other pipes relevant for distribution system connectivity.

Demand Allocation

- Create a linkage between CITY water meter GIS features and an export of CITY CIS information based on a unique meter or customer ID that is found in both the GIS water meter and CIS data. Use water usage data from the CITY CIS to determine the annual average customer water usage and use the water meter locations to distribute the demand across the distribution system.
 - Training documentation on the demand allocation process that includes the process of updating the CITY CIS data and distributing the revised demands across the distribution system.
- Create a linkage between CITY water meter GIS features and an export of CITY CIS information based on a unique meter or customer ID that is found in both the GIS water meter and CIS data. Use water usage data from the CITY CIS to determine the annual average wholesale water usage and use the water meter locations to distribute the demand across the distribution system.

 Determine nonrevenue water and incorporate into the water demand projections and the demand allocation.

 Summarize annual average, winter average, and maximum month water usage by pressure zone and customer class.

Diurnal Analysis

- Summarize historical peak hour factors, minimum hour factors, and equalization storage factors for the maximum day demand by pressure zone.
- Extended Period Simulation (EPS) Development
 - Collect data needed to develop EPS capability in the model.
 - EPS functionality for water age analysis of the existing distribution system under average day and maximum day demand conditions. EPS functionality for hydraulic analysis of the existing distribution system under the maximum day demand condition.
- Existing System Model Calibration Verification
 - Calibration verification, via static analysis in the model, utilizing data collected from field testing.
 - Interview CITY staff tasked with operating system facilities to incorporate control schemes for EPS calibration verification.
 - Field testing for calibration verification.
 - Prepare static and extended period model simulations with the demand allocation for calibration verification.
- Conduct up to two days of model training.
- Raw Water System Model
 - Review and update existing model to include up to three production scenarios.
 - Update raw water system features and summarize general operational production strategies and settings.
 - Compare the hydraulic analysis results of the new model with the existing model.
 - o Peak and diurnal demand factors: not applicable to the raw water model.
 - Model Calibration Verification
 - Calibration verification, via static analysis in the model, utilizing data collected from field testing.
 - Interview CITY staff tasked with operating raw water system facilities for calibration verification.
 - o Field testing for calibration verification.

Evaluate field testing data for calibration verification.

Conservation Efforts

- Provide recommendations for conservation strategies and/or projects that reduce the average day demand and peak hour demand.
- Evaluate options and determine feasibility and benefits of leak detection for the distribution system. If an option is feasible, provide a recommendation for implementation of one option.

• Emergency Preparedness

- Evaluate and provide recommendations for facilities requiring emergency preparedness to include backup power supply, redundant piping, treatment, and water supplies.
- Water Distribution System Capital Improvements Plan (CIP) Review and Development
 - Review existing water distribution system related projects, not currently under design or construction, which are scheduled for implementation between 2017 and 2025. Based on the results of the hydraulic model, develop capital improvements for the water distribution system for the year 2020, 2035, and 2045 planning periods and classify as hydraulic, development driven, or fire flow related.
 - Assess rate stability and debt service coverage implications with the CIP to include the following:
 - Evaluate current usage levels and prepare revenue forecast.
 - Project capital flow of funds.
 - Project operating revenue requirements.
 - Review and finalize operating cash flow.
 - Non-economic evaluations for non-linear capital improvements associated with failure, regulatory factors, and/or general practices risk.
 - Opinions of probable construction cost and prioritization for all CIP projects; prioritization will be classified as hydraulic, development driven, or fire flow related improvements. The proposed implementation year and/or demand trigger based on the demand projections for hydraulic related CIP projects will be determined; hydraulic related improvements have the highest priority.
- Mapping for capital improvements map including existing water distribution system projects and
 the capital improvements recommended in this Water Master Plan. Fire flow and pressure
 contour mapping will be developed for the existing system and planning periods where
 applicable.

* * * * *

3.0 WATER DEMANDS

This section of the report characterizes the City's water service area, evaluates the historical retail and wholesale water usage, summarizes historical water demands, summarizes the range of the City-approved water demand projections from the 2013 Water Demand Assessment (WDA, by others), and develops the water demand projection applied to the master planning and hydraulic modeling efforts for this project/report.

3.1 Water Service

The Wichita water service area is represented by the City's retail and wholesale customer classifications. In 2015, the retail service area included approximately 145,000 customer accounts (or meters with unique premise numbers in the customer billing system). Retail customers reside within the City limits and represent over 91 percent of the total water sales for the water service area. Wholesale water sales is represented by ten customer accounts that receive potable water from a single location, or master meter, and one customer, the City of Bentley, which receives non-potable water from the Equus Beds Well Field (EBWF). The potable water wholesale customers represented approximately 9 percent of the total water sales in 2015. For clarity, the City does not own or operate the water distribution network downstream of the wholesale customer master meter connection points and, therefore, there is no reference to a "wholesale service area" because water service from the City stops at a master meter. Additionally, all references to wholesale customers are in regard to the wholesale potable water users from this point forward in the report.

3.2 Retail Water Usage

Retail water sales include both residential and commercial customer classes and collectively represented an average sales of approximately 92 percent of the total sales volume from 2006 to 2015. Water sales for a City Use-type classification is sequestered, as the sales volume between 2006 and 2015 only ranged between 0.1 and 0.2 percent of the total retail sales; therefore, City Use is included in the commercial customer class which is also consistent with its billing classification.

Historical data representing residential and commercial meter counts, average day sales, and metered water usage (represented in gallons per meter-day (gpmd)) is listed in Table 3.1. The average commercial metered usage (1,600 gpmd) from 2006 to 2011 is approximately 8 times greater than the average residential metered usage (203 gpmd). During the same period, the residential and commercial average day sales are approximately 56 percent and 44 percent, respectively, of the retail water sales. The commercial customer class has a large impact on water demands in the distribution system which is

Table 3.1
Historical Retail Water Usage

Year		Meter Count ^{1,2}		Aver	age Day Sales ^{1,2} (I	MGD)	Me	etered Usage (gpn	nd)	
Tear	Residential	Commercial	Total	Residential	Commercial	Total	Residential	Commercial	Combined	
1991			118,447			61.2			517	
1992			116,498			55.5			477	
1993			127,964			57.1			447	
1994			116,499			57.0			489	
1995			179,594			53.3			297	
1996			126,163			54.5			432	
1997			128,341			52.4			409	
1998			130,257			61.0			469	
1999			132,260			55.0			416	
2000			132,260			60.8			460	
2001			132,228			61.3			464	
2002			135,552			57.5			424	
2003			133,487			55.4			415	
2004			133,791			54.9			410	
2005			137,234			59.9			436	
2006	121,942	12,182	134,124	29.4	22.8	52.2	241	1,868	389	
2007	123,608	12,347	135,955	26.4	21.4	47.7	213	1,729	351	
2008	125,064	12,510	137,574	24.7	20.5	45.2	198	1,638	329	
2009	126,002	12,638	138,640	25.0	19.4	44.4	198	1,535	320	
2010	126,874	12,733	139,607	26.8	20.8	47.6	211	1,630	341	
2011	127,279	12,844	140,123	28.4	21.3	49.8	223	1,660	355	
2012	128,144	12,973	141,117	27.6	21.0	48.6	216	1,620	345	
2013	128,934	13,078	142,012	22.5	18.6	41.1	174	1,423	289	
2014	130,127	13,242	143,369	23.7	19.5	43.2	182	1,473	301	
2015	131,550	13,435	144,985	22.2	19.2	41.4	169	1,428	286	

^{1.} Data from 1991 to 2005 collected from the City's Annual Water Use Reports.

^{2.} Data from 2006 to 2015 collected from the City's customer billing system; meter count is determined as the unique premise number tied to each customer account in the customer billing system.

evidenced by accounting for nearly half of the total average day sales from only about 9 percent of the total meters in the distribution system.

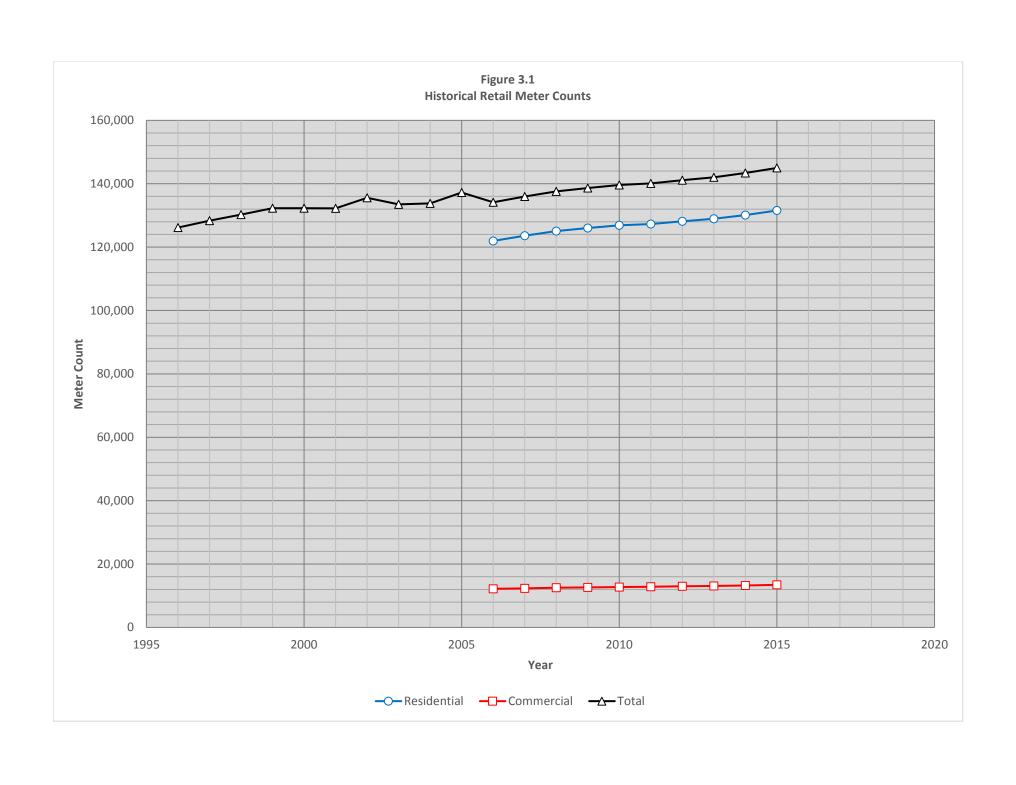
There is a steady, but escalating, trend in meter counts on an annual basis since 2006 and is illustrated in Figure 3.1. The average increase in residential meters from 2006 to 2015 and from 2011 to 2015 is the same at approximately 1,068 meters per year. The average increase in commercial meters from 2006 to 2015 and from 2011 to 2015 is approximately 139 and 148 meters per year. In conclusion, residential customer additions have been consistently increasing over the last 10 years and commercial meter additions have slightly accelerated over the last 5 years.

The average day sales and metered water usage has been declining since 2006 and is illustrated in Figure 3.2. An escalating meter count coupled with declining average day sales and metered water usage can be representative of successful water conservation strategies, water efficient fixtures, public education, and water rate structures.

3.3 Wholesale Customers

The City's wholesale customers include Rural Water District (RWD) No.'s 1, 3, 5, and 8 (RWD No.'s 5 and 8 are evaluated as a single wholesale customer) and the cities of Bel Aire, Park City, Kechi, Benton, Rose Hill, Valley Center, and Derby. Water is delivered to each wholesale customer from the City's distribution system to a master meter which and, for the purposes of this report, is considered the end of the line with respect to the City's responsibility for providing contracted quantities of water at adequate pressure, where applicable, and in compliance with Safe Drinking Water Act (SDWA) as stated in each contract. For clarity, there are no wholesale customer contracts with specific conditional pressure requirements other than generalizing it as adequate pressure. A general summary of the contract terms for water supply of each wholesale customer is listed in Table 3.2.

The historical average day sales for each wholesale customer is listed in Table 3.3. Since 2006, the average day sales for Derby represent approximately 54 percent of the total wholesale customer sales on an annual basis. Review of the table indicates that average day sales have been relatively stable since 2006 across all wholesale customers. The minimum, average, and peak sales from 2006 to 2015 are 3.6 MGD, 4.1 MGD, and 4.8 MGD, respectively, for all wholesale customers combined. Additionally, excluding years 2011 and 2012, which are representative of dry years, the net change in average day sales is approximately 121 gpm.



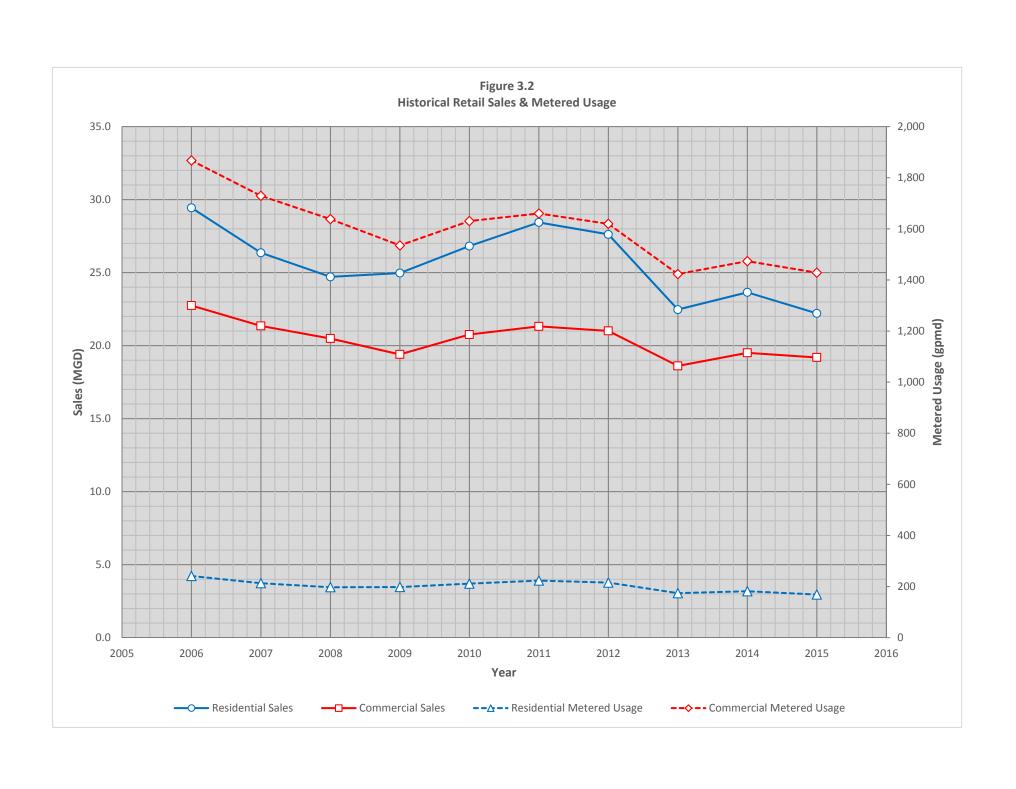


Table 3.2
Wholesale Customer Contract Conditions 1

	Averag	ge Daily Cont	tract Amoun	t (gpm)			Contract C	Conditions	r End Year Type									
Customer		by Planni	ng Period ²		Supply Type	2015 Annual	Pressure	Start Year	End Voor	Tuno								
	2015	2020	2035	2045	Supply Type	Volume (MG)	Pressure	Start Year	Elia feal	Туре								
RWD No. 1	71	81	81 Note 3 Note 3 Annual Volume		37.4	Adequate	2010 2030		Take or Pay 50%									
RWD No. 3	342	371	Note 3	Note 3	Annual Volume	179.7	Not Applicable	1996	2016	Take or Pay 50%								
RWD No.'s 5 & 8	73	84	Note 3	Note 3	Annual Volume	38.3	Not Applicable	1996	2016	Take or Pay 50%								
Bel Aire	546	603	Note 3	Note 3	Annual Volume	287.0	Adequate	2008	2028	Take or Pay 50%								
Park City	1,185	1,402	Note 3	Note 3	Annual Volume	623.1	Not Applicable	1985	2025	Pay as you go								
Kechi	124	133	Note 3	Note 3	Annual Volume	65.0	Not Applicable	1997	2024	Take or Pay 50%								
Benton	63	Note 3	Note 3	Note 3	Annual Volume	33.0	Not Applicable	1975	2015	Pay as you go								
Rose Hill	628	723	Note 3	Note 3	Annual Volume	330.0	Adequate	1982	2022	Pay as you go								
Valley Center	594	Note 3	Note 3	Note 3	Annual Volume	312.2	Not Applicable	1997	2016	Take or Pay 50%								
Derby	1,735	1,870	Note 3	Note 3	Annual Volume	912.0	Adequate	2001	2022	Take or Pay 100%								

- 1. The contract conditions listed in this table are intended to be a general summary of the conditions relative to this Water Master Plan and are not all inclusive.
- 2. Planning periods listed represent the years evaluated in this Water Master Plan.
- 3. Contract expires before the planning period indicated in the column.

Table 3.3
Historical Wholesale Customer Sales

Year					Average Day S	Sales ^{1,2} (gpm)					Total	Total
Teal	RWD No. 1	RWD No. 3	RWD No. 5 & 8	Bel Aire	Park City	Kechi	Benton	Rose Hill	Valley Center	Derby	(gpm)	(MGD)
1991	51	99	0	343	124	40	42	194	0	0	893	1.3
1992	1	106	0	267	104	41	40	179	0	0	738	1.1
1993	60	20	0	289	73	41	40	184	0	0	707	1.0
1994	52	1	57	365	82	49	43	217	0	0	866	1.2
1995	53	0	60	340	79	50	45	205	0	0	832	1.2
1996	57	1	55	374	77	58	49	219	0	0	889	1.3
1997	51	0	0	0	0	0	48	215	0	0	315	0.5
1998	0	0	0	0	0	0	0	0	0	0	0	0.0
1999	53	3	62	0	0	0	49	213	0	0	380	0.5
2000	64	1	62	507	72	77	58	247	366	0	1,453	2.1
2001	39	14	62	514	87	90	49	225	507	0	1,588	2.3
2002	66	5	67	490	97	97	52	233	421	0	1,527	2.2
2003	18	1	90	300	45	96	54	228	421	0	1,254	1.8
2004	16	0	55	272	79	87	48	205	384	0	1,147	1.7
2005	21	5	58	255	88	98	53	221	432	1,412	2,645	3.8
2006	59	1	66	245	72	102	0	228	440	1,475	2,689	3.9
2007	56	2	60	221	101	96	0	216	396	1,400	2,550	3.7
2008	48	16	58	273	87	82	0	210	377	1,333	2,483	3.6
2009	50	0	56	192	100	101	0	201	384	1,420	2,504	3.6
2010	61	10	60	234	102	112	0	218	424	1,558	2,779	4.0
2011	64	249	72	199	161	114	13	197	401	1,840	3,310	4.8
2012	62	319	67	262	186	117	48	209	405	1,665	3,340	4.8
2013	51	261	65	266	99	92	42	204	358	1,425	2,863	4.1
2014	54	267	62	241	108	103	44	191	365	1,563	2,997	4.3
2015	52	255	60	214	106	93	41	192	308	1,492	2,812	4.0

^{1.} Data from 1991 to 2005 collected from the City's Annual Water Use Reports.

^{2.} Data from 2006 to 2015 collected from the City's customer billing system; meter count is determined as the unique premise number tied to each customer account in the customer billing system.

The historical metered consumption and contract water supply volumes from 2006 to 2015 for each wholesale customer are illustrated in Figure 3.3. On average since 2011, RWD No.'s 1, 3, 5/8, Kechi and Derby utilized over 80 percent of their respective contract amounts. Bel Aire, Benton, Rose Hill, and Valley Center utilized between 34 and 65 percent over the same period; and Park City utilized approximately 12 percent of the contract amount. The metered consumption portion of the contract amount on annual basis for each wholesale customer is listed in Table 3.4; maximum, average, and minimum portions for the data ranges from 2006 to 2015 and from 2011 to 2015 are also listed in Table 3.4.

3.4 Seasonal Water Consumption

Monthly average day sales data from 2006 to 2015 was evaluated to determine seasonal characteristics for water consumption. The average day sales by month during this period is listed in Table 3.5. Four demand seasons were sequestered by averaging monthly sales and evaluating a running total for all 12 months within a 3 month selection. This evaluation identifies the months that fall into the categories listed below:

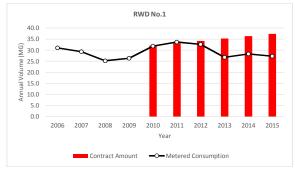
- High demand season: July, August, and September;
- Moderately high demand season: April, May, and June;
- Moderately low demand season: October, November, and December; and
- Low demand season: January, February, and March.

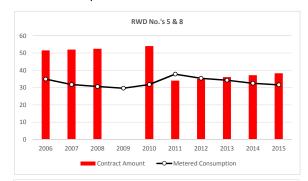
Recent historical monthly average day sales from 2011 to 2015 for the residential, commercial, wholesale, and utility customer classifications is illustrated in Figures 3.4, 3.5, 3.6, and 3.7; the total for all customer classes is illustrated in Figure 3.8. The residential, commercial, and wholesale customer classifications reflect the seasonal demand characteristics described in the paragraphs above. The utility classification is fairly consistent, but does include periodic months in which the average day sales double. Utility average day sales represent a fraction of the total; since 2006 average day sales have not exceeded more than 0.16 percent of the total.

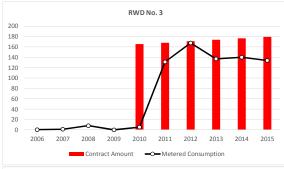
3.5 Large Users

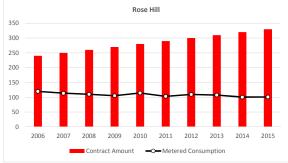
The top twenty large users from 2011 to 2015 were filtered from the average day sales data provided by the City to compare rankings from year to year and is illustrated in Figure 3.9. This data format exposes significant increases or losses in average day sales that is representative of customer gains and losses. Approximately 75 percent of the large users over this time period have average day sales ranging from approximately 35 gpm to 100 gpm. The top 2 large users have held their ranking since 2011; their

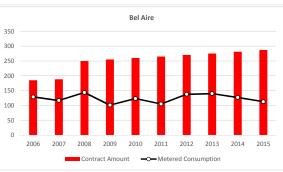
Figure 3.3
Historical Contract Amounts vs. Metered Consumption

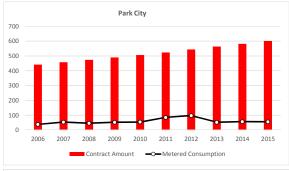




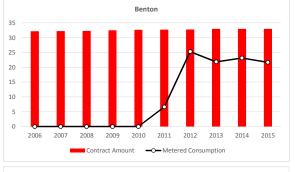


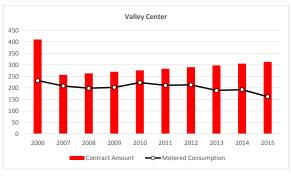












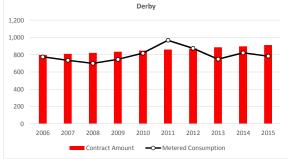


Table 3.4
Metered Consumption Portion of Water Supply Contract Amount

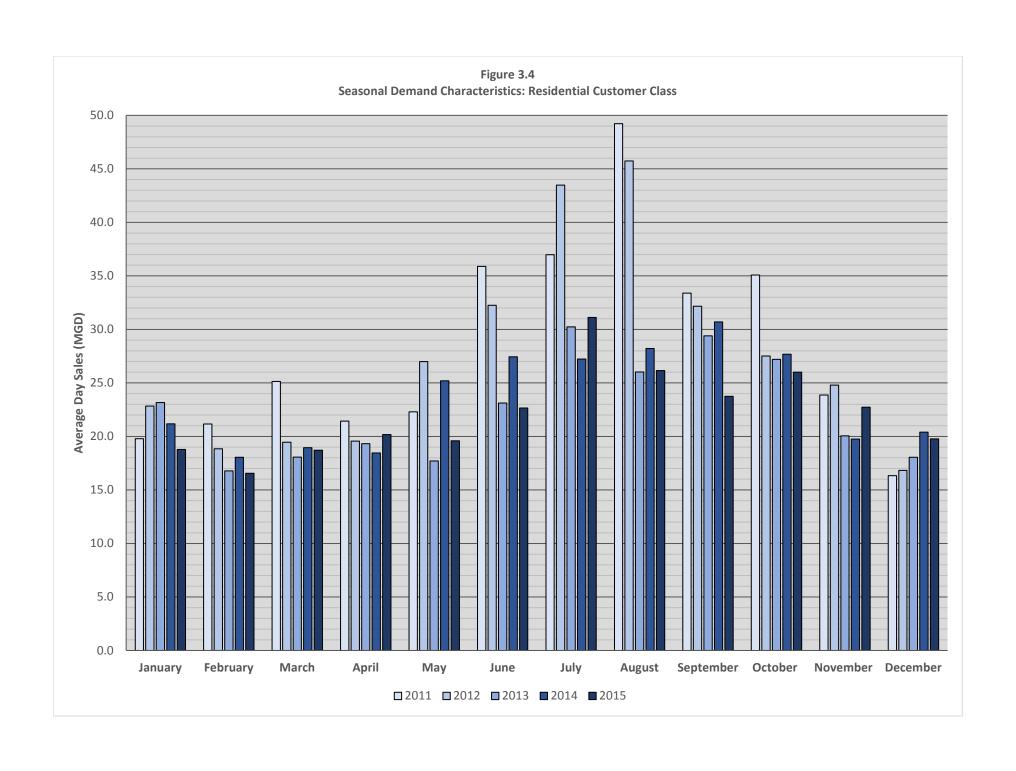
Year(s)	RWD No. 1	RWD No. 3	RWD No. 5 & 8	Bel Aire	Park City	Kechi	Benton	Rose Hill	Valley Center	Derby
2006			68%	70%	9%	95%		50%	56%	97%
2007			61% 62%		12%	88%		45%	81%	91%
2008	58% 57%		57%	10%	74%		42%	75%	85%	
2009	2009		40%	11%	89%		39%	75%	90%	
2010	99%	3%	59%	47%	11%	97%		41%	81%	97%
2011	102%	78%	111%	40%	16%	98%	20%	36%	75%	112%
2012	95%	98%	101%	51%	18%	98%	77%	37%	73%	100%
2013	76%	79%	95%	51%	9%	76%	66%	35%	63%	85%
2014	78%	79%	87%	45%	10%	84%	70%	31%	63%	91%
2015	73%	75%	82%	39%	9%	75%	66%	31%	52%	86%
					Data Range					
2006-2015										
Max	102%	98%	111%	70%	18%	98%	77%	50%	81%	112%
Average	87%	69%	80%	50%	11%	87%	60%	39%	70%	93%
Min	73%	3%	58%	39%	9%	74%	20%	31%	52%	85%
2011-2015										
Max	102%	98%	111%	51%	18%	98%	77%	37%	75%	112%
Average	85%	82%	95%	45%	12%	86%	60%	34%	65%	95%
Min	73%	75%	82%	39%	9%	75%	20%	31%	52%	85%

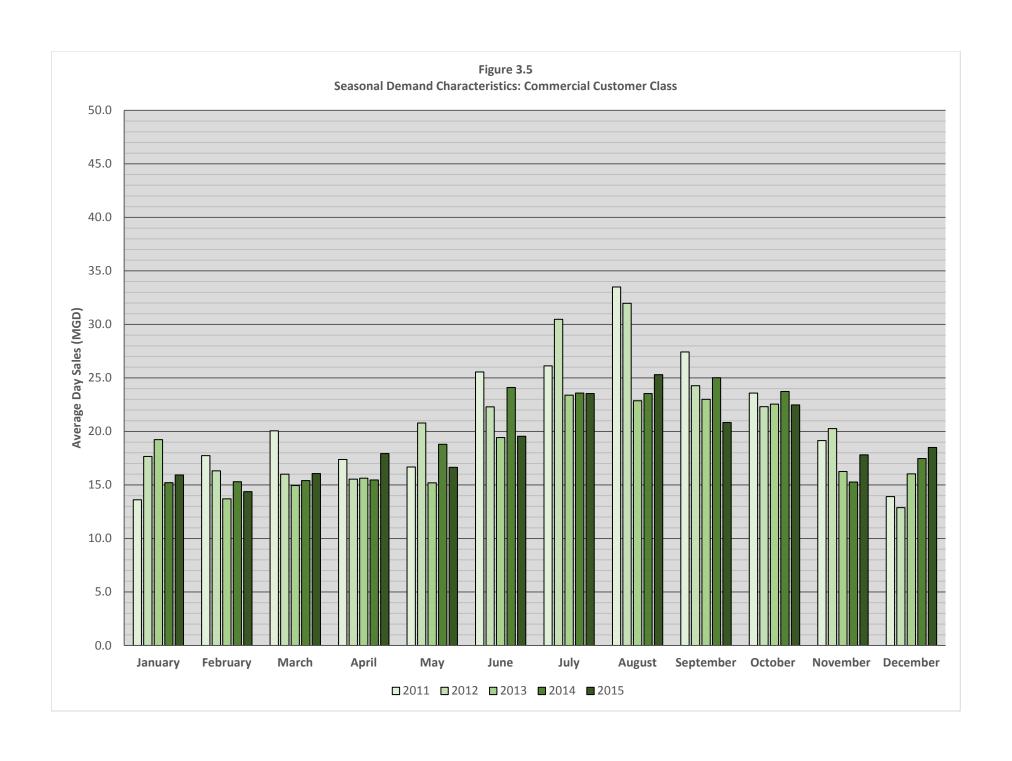
1. The metered consumption portions listed above are based on the data illustrated in Figure 2.3 with respect to the annual contract amounts.

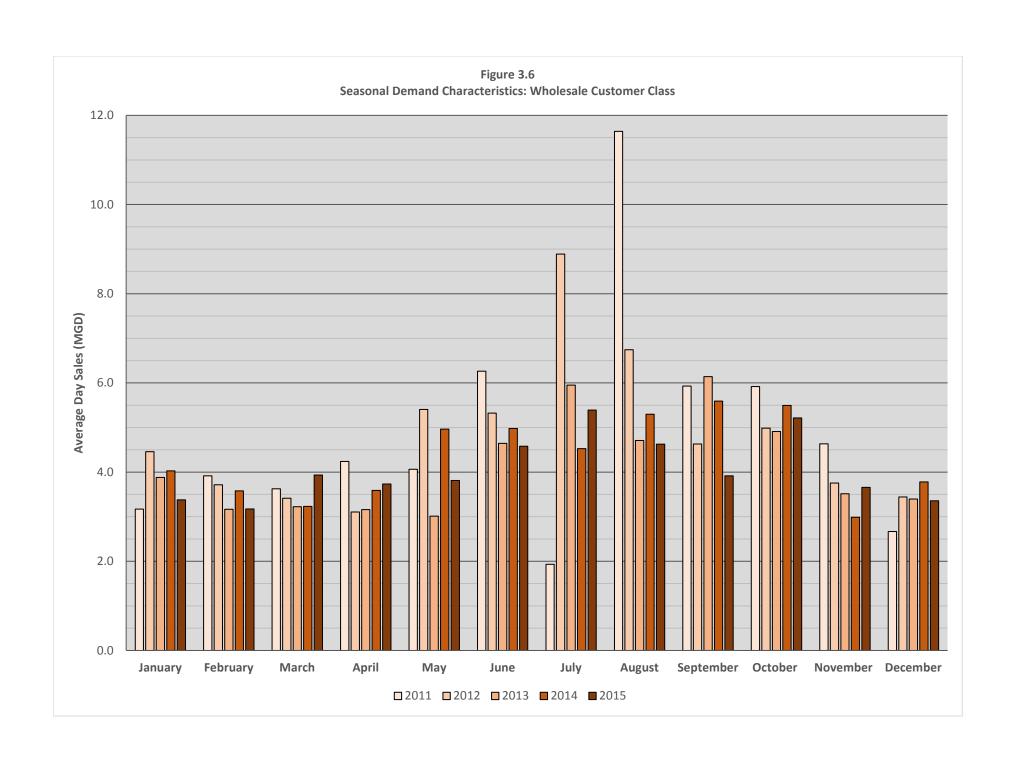
Table 3.5
Seasonal Demand Evaluation

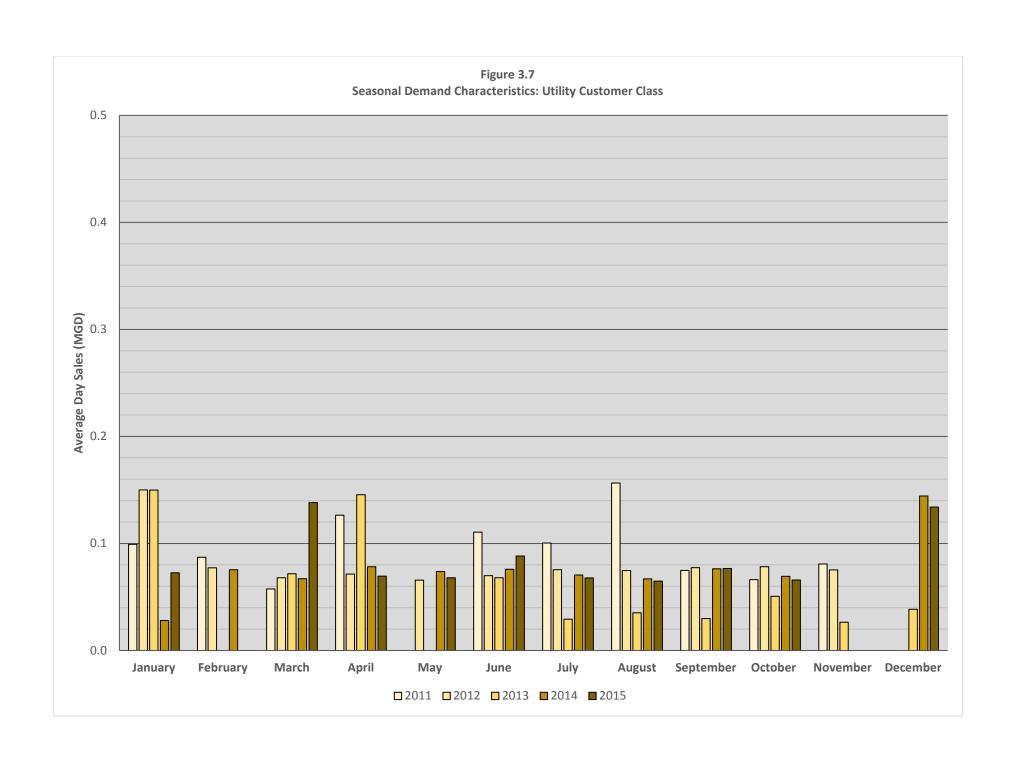
		Demand Season (MGD)														
Year		Low			Moderately Hig	;h		High			Moderately Lov	v				
	January	February	March	April	May	June	July	August	September	October	November	December				
2006	43.6	39.2	45.9	46.8	55.6	67.4	72.8	78.3	67.6	66.6	47.2	40.6				
2007	36.0	46.2	49.4	40.0	41.8	54.4	54.0	78.8	65.1	64.9	52.3	33.8				
2008	50.8	49.5	40.1	37.5	45.8	47.8	57.2	65.1	63.4	51.9	31.7	44.1				
2009	47.0	40.0	40.3	42.6	39.0	63.6	63.5	60.9	56.7	48.8	42.5	30.8				
2010	40.2	39.9	41.9	40.1	41.0	63.3	69.2	74.6	64.2	57.8	46.6	39.7				
2011	36.7	36.7 42.9		43.2	43.0	67.8	65.1	94.5	66.8	64.6	47.7	32.9				
2012	45.1 39.0 38		38.9	38.3	53.3	59.9	82.9	84.5	61.1	54.9	48.9	33.2				
2013	46.4	33.6	36.3	38.2	35.9	47.3	59.6	53.6	58.6	54.7	39.9	37.5				
2014	40.4	37.0	37.6	37.6	49.0	56.6	55.4	57.1	61.4	57.0	38.0	41.8				
2015	38.2	34.1	38.9	41.9	40.1	46.9	60.1	56.1	48.6	53.8	44.2	41.8				
Monthly Average ¹	42.4	40.1	41.8	40.6	44.5	57.5	64.0	70.4	61.3	57.5	43.9	37.6				
Running Total ²		124.4			142.6			195.7			139.0					
Seasonal Average ³		41.5			47.5			65.2			46.3					

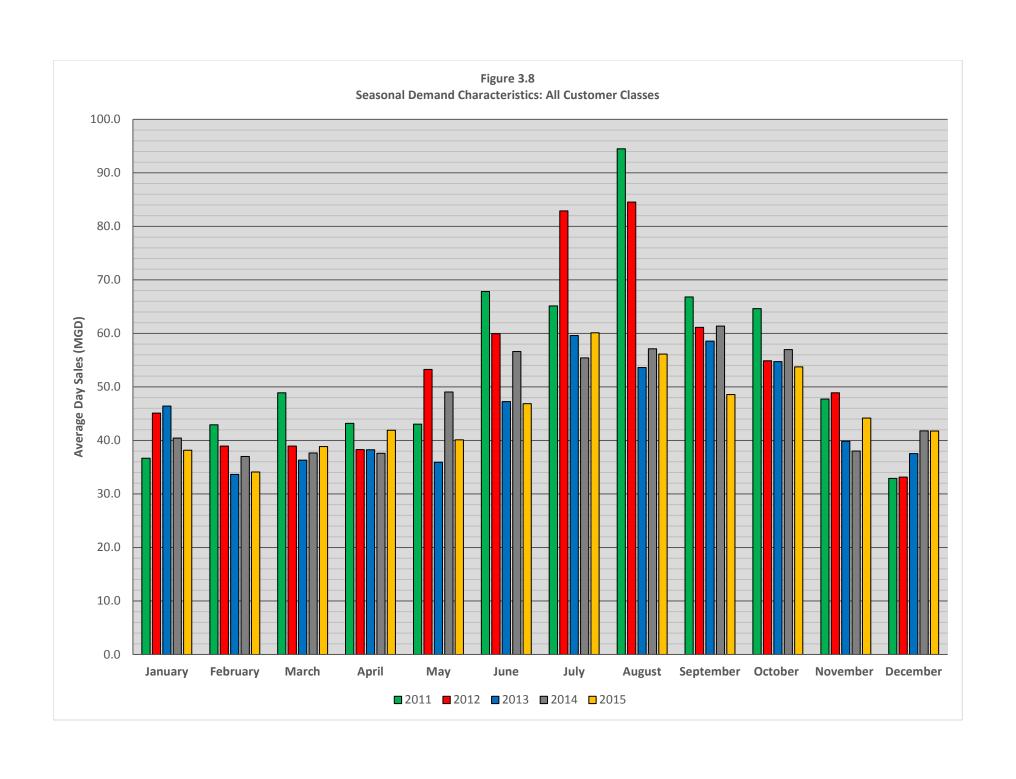
- 1. Monthly average is based on years 2006 through 2015.
- 2. Running total is the summation of the monthly averages within the respective demand season
- 3. Seasonal average is based on the monthly average within the respective demand season

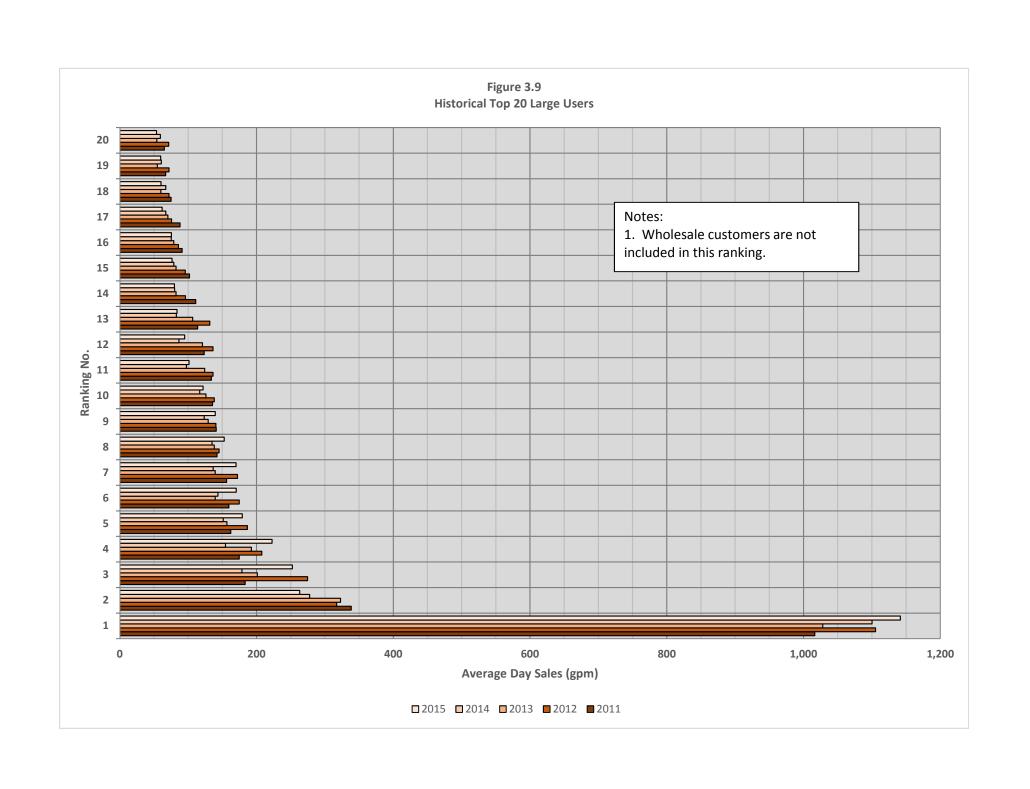












premise numbers are 33450 and 34883 respectively. The demand allocation in the model for the top twenty large users is done manually for quality assurance.

3.6 Water Demand Projections

The 2013 WDA developed a range of population-based water demand projections through 2060; references to information from the 2013 WDA in this report are tied to the planning periods evaluated in this Water Master Plan (WMP) for years 2015, 2020, 2035, and 2045. High, medium, and low growth water demand projections were developed in the 2013 WDA for the entire service area (retail and wholesale combined). The City also prepared average day demand projections that were presented in the 2015 Water Resources Plan through 2060.

A population-based approach is an effective method for projecting a range of potential water demands at a low level and a good secondary check if other approaches are used; however, there are inherent inconsistencies with a population-based projection as it relates to the City of Wichita which are described below:

- Population-based demand projections assume the entire population is served by the City and the entire population uses City water for all water use needs;
- Population-based demand projections do not consider customers that provide their own law
 watering irrigation systems from private wells, industrial customers, or acknowledge the impact
 commercial customers have on the total demand and the distribution system;
- Dry year water usage is not incorporated; gpcd only considers metered WTP flow for a selected year for the entire projection period;
- The projection granularity is insufficient for master planning with respect to wholesale customers because it requires a projection for each wholesale customer so they are evaluated at their respective metering locations; and
- A gpcd value can overestimate water demand for wholesale customers with little or no commercial presence in their communities.

The water demand projections are based on projected meter counts by customer class for the retail consumption, a combination of contract maximums and escalating projections from current sales to the contract maximums for wholesale customers, nonrevenue water, and dry year water use adder. This approach removes inherent inconsistencies described above and accounts for:

- The metered population purchasing water from the City;
- Specific water use trending for residential and commercial customer classes;

 Allocating future demand based on development characteristics for residential versus commercial;

- Historical consumption trending paired with contracted amounts for wholesale customer usage;
 and
- Recent historical review of wet and dry years to develop a dry year water use adder for both residential and commercial customer classes.

A comprehensive historical summary since 2006 of the retail and wholesale average day sales, average day and maximum day demands, nonrevenue water, and the water demand projections with the dry year adder described above is listed in Table 3.6 and illustrated in Figure 3.10.

3.6.1 Retail Component

The retail customer component of the water demand projections is based on recent historical water usage in gallons per meter day (gpmd) and meter projections. The average water usage since 2013 is approximately 175 gpmd and is the baseline for the projecting water demand beginning in 2016. The recent high water use period occurred in 2011 and 2012 and is applied in the dry year water use component of the demand projections. Retail meter projections are based on 1,070 meters per year with a baseline of 131,550 meters from the year 2015.

The commercial customer component of the water demand projections is consistent with retail component. The average water usage since 2013 is 1,287 gpmd and is the baseline for projecting water demand beginning in 2016. Commercial meter projections are based on 150 meters per year with a baseline of 13,435 meters from the year 2015.

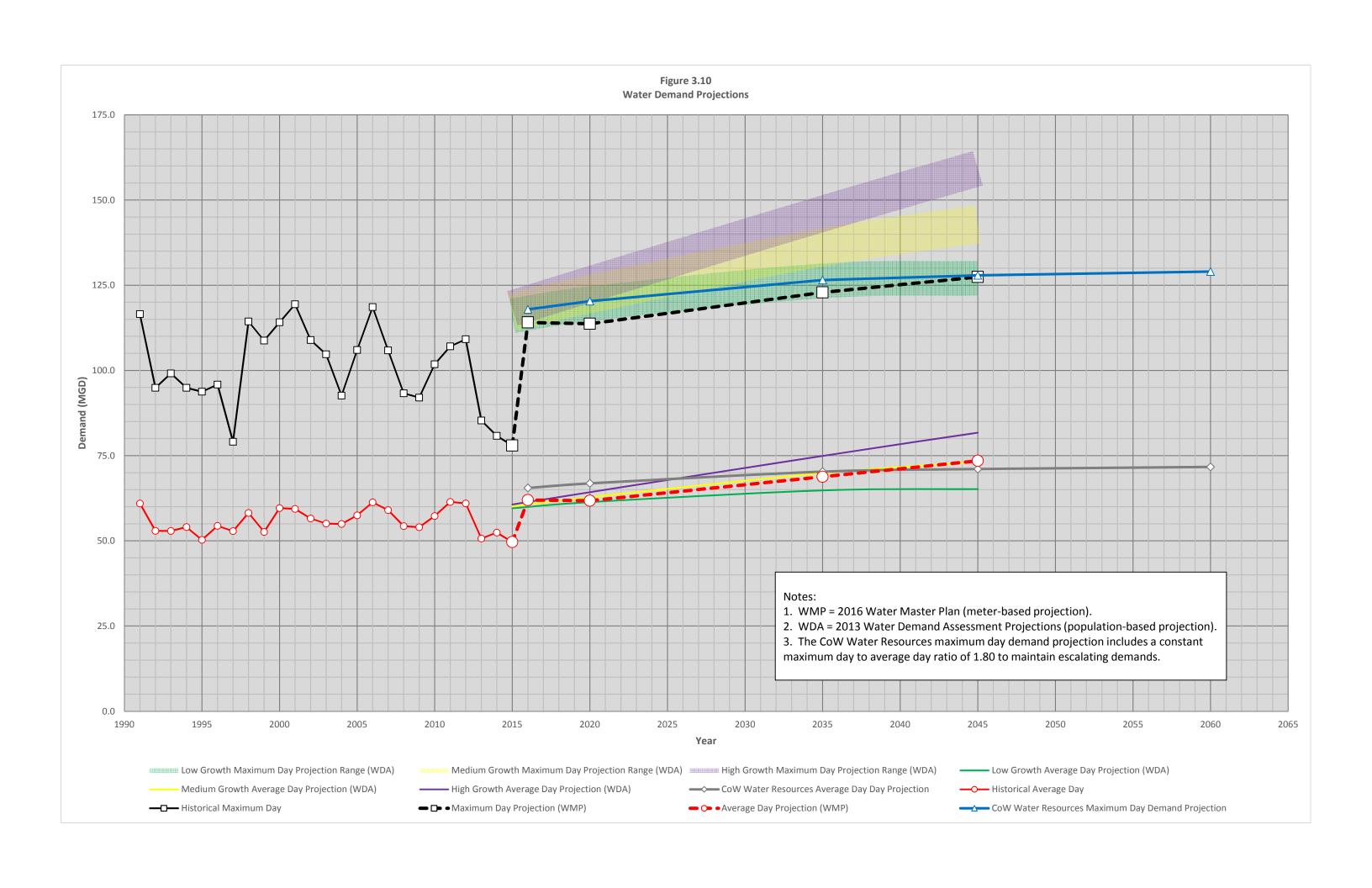
Spirit is the City's largest commercial water user and has averaged approximately 1.6 MGD annually since 2011. Beginning in 2017, Spirit's water supply needs will be accomplished with 40 percent reuse water and in 2018 and beyond the long term plan includes 70 percent reuse. However, the City is still responsible for providing Spirit's entire water supply need on an emergency basis if reuse water is unavailable. Therefore, the average day demand projections include the reduction in water supply due to reuse and the maximum day demand projections include their recent historical peak demand of approximately 2.5 MGD (no reuse present) which occurred in 2013.

Table 3.6
Water Demand Projections

										Meter-E	Based Projectio	ns										Water Resources Plan Projections		
						Retail							R	etail & Wholesa	ile				Average	Maximum	Maximum	Average	Maximum	Maximum
Year		Meter Count		Metered Usage (gpmd)		Dry Year Adder (gpmd)		Project	Projected Water Usage (gpmd)		Average Day Sales (MGD)				Nonrevenue	Nonrevenue (MGD)	Day	Day ³	Day	Day	Day ³	Day		
	Residential	Commercial	Spirit	Residential	Commercial	Spirit ¹	Residential	Commercial	Residential	Commercial	Spirit	Residential	Commercial	Spirit	Wholesale ²	Total	Amount	(IVIGD)	(MGD)	(MGD)	Factor	(MGD)	(MGD)	Factor
2006	121,942	12,182		241	1,868							29.4	22.8		3.9	56.1	9%	5.2	61.3	118.6	1.94			
2007	123,608	12,347		213	1,729							26.4	21.4		3.7	51.4	13%	7.6	59.0	105.9	1.79			
2008	125,064	12,510		198	1,638							24.7	20.5		3.6	48.8	10%	5.5	54.3	93.3	1.72			
2009	126,002	12,638		198	1,535							25.0	19.4		3.6	48.0	11%	6.0	54.0	92.0	1.70			
2010	126,874	12,733	14	211	1,630	195,576						26.8	20.8	2.7	4.0	54.3	5%	3.0	57.3	101.8	1.78			
2011	127,279	12,830	14	223	1,253	180,682						28.4	16.1	2.5	4.8	51.8	16%	9.6	61.4	107.1	1.74			
2012	128,144	12,959	14	216	1,245	177,307						27.6	16.1	2.5	4.8	51.0	16%	9.9	61.0	109.2	1.79	-		
2013	128,934	13,064	14	174	1,228	183,143						22.5	16.0	2.6	4.1	45.2	11%	5.5	50.7	85.3	1.68			
2014	130,127	13,228	14	182	1,190	204,703						23.7	15.7	2.9	4.3	46.6	11%	5.9	52.4	80.8	1.54			
2015	131,550	13,421	14	169	1,160	217,625						22.2	15.6	3.0	4.0	44.9	10%	4.8	49.7	78.0	1.57			
2016	132,620	13,571	14	175	1,193	192,692	45	56	220	1,249	192,692	29.1	16.9	2.70	7.0	55.8	11%	6.1	62.0	114.1	1.80	65.5	117.9	1.80
2020	136,900	14,171	14	175	1,193	57,808	45	56	220	1,249	57,808	30.1	17.7	0.81	7.0	55.6	11%	6.1	61.8	113.7	1.80	66.9	120.3	1.80
2035	152,950	16,421	14	175	1,193	57,808	45	56	220	1,249	57,808	33.6	20.5	0.81	7.0	62.0	11%	6.8	68.8	122.9	1.75	70.3	126.5	1.80
2045	163,650	17,921	14	175	1,193	57,808	45	56	220	1,249	57,808	36.0	22.4	0.81	7.0	66.2	11%	7.3	73.5	127.4	1.70	71.1	127.9	1.80

- 1. Projected Spirit water usage assumes 40 percent reuse beginning in 2017 and 70 percent reuse in 2018 through 2045; this is eqivalent to 60 percent and 30 percent of the historical average in 2017 and 2018 through 2045. Spirit's 2016 metered usage is based on the historical average from 2011 to 2015.
- 2. RWD No.'s 1, 3, 5/8, Kechi, Benton, Valley Center, and Derby projections at the contract maximum. Bel Air and Rose Hill projections are estimated at 75 percent of their contract maximum.
- 3. Maximum day demand projections include 2.5 MGD for Spirit; CoW is responsible for providing all Spirit water demand if reuse capability cannot be provided. The maximum day demand for Spirit in 2013 was 2.47 MGD.

City of Wichita, Kansas



3.6.2 Dry Year Water Use Adder

Incorporating a dry year water use adder in the demand projections is a conservative approach because a dry year will eventually reoccur. Representative dry and wet periods have occurred in the last 5 years. In 2011 and 2012, the metered water usage (in gallons per meter-day, gpmd) peaked and represents a dry period; the average water usage was 219 gpmd and 1,325 for residential and commercial respectively. From 2013 to 2014, the metered water usage was at a 10-year low and, more specifically, 2014 and 2015 were wet years; the average water usage from 2013 to 2015 was 175 gpm and 1,287 gpmd for residential and commercial respectively. The dry year water use adder is the difference between average water use between the dry and wet periods described above. The water demand projections are based on the water usage listed below for retail customers:

- Residential:
 - Base water usage = 175 gpmd;
 - Dry year water use adder = 45 gpmd; and
 - o Projected water usage = 220 gpmd.
- Commercial:
 - o Base water usage = 1,287 gpmd;
 - O Dry year water use adder = 37 gpmd; and
 - o Projected water usage = 1,325 gpmd.

3.6.3 Wholesale Component

The wholesale customer component of the water demand projections is based on historical average and maximum metrics for average day sales pairings by two time periods between 2006 and 2015 and from 2011 to 2015 relative to their maximum contract amounts. The demand projections are based on the criteria listed below; the corresponding wholesale customers that apply are also listed with their projection:

- If the average sales amount is greater than 50 percent and the maximum amount is greater than 70 percent in either time period (from 2006 to 2015 or from 2011 to 2015), then the maximum contract amount is applied:
 - \circ RWD No. 1 = 81 gpm;
 - \circ RWD No. 3 = 371 gpm;
 - o RWD No. 5/8 = 84 gpm;
 - \circ Kechi = 133 gpm;
 - \circ Benton = 63 gpm;
 - o Valley Center = 594 gpm;

- \circ Derby = 1,870 gpm.
- If the average sales amount is between 30 and 50 percent and the maximum amount is between 50 and 70 percent in either time period, then 75 percent of the maximum contract amount is applied:
 - \circ Bel Aire = 452 gpm;
 - o Rose Hill = 542 gpm.
- If the average sales amount is between 10 and 30 percent and the maximum amount is between 10 and 50 percent in either time period, then 50 percent of the maximum contract amount is applied:
 - o Park City = 701 gpm.

For clarity, the demand projections listed above apply to all planning periods evaluated in this Water Master Plan.

3.6.4 Nonrevenue Water

Nonrevenue water is determined as the difference between the WTP HSPS metered flow and the total customer metered sales (retail and wholesale). Nonrevenue water ranged from 8 percent to 13 percent since 2006 and averaged approximately 11 percent. Since 2011, nonrevenue water is descending, from 11 percent to 8 percent, and can be related, but not limited to, the decline in average day sales. The nonrevenue component included in the water demand projections is 11 percent based on recent historical information and the assumption that demand projections will escalate as the City grows to the 2045 planning period.

3.6.5 Maximum Day Demand Factor

Since 2006, the maximum day to average day ratio (or maximum day factor) ranged from 1.54 to 1.94, with an average of 1.73. Recent historical maximum day factors since 2012 include a value of 1.79 occurring in 2012; 2014 and 2015 are representative of wet years and recorded the lowest factors since 2006 of 1.54 and 1.57 respectively. Since 2006, the maximum day factor has been descending, therefore, the projections begin conservatively with a high factor of 1.80 beginning in 2016 and the trend of descending factors is anticipated to continue through the planning periods evaluated. The factors for each planning period are as follows:

- Year 2020 at 1.80;
- Year 2035 at 1.75; and
- Year 2045 at 1.70.

3.6.6 Conclusion

The meter-based water demand projections discussed in Section 3.6 and the population-based water demand projections from the 2013 WDA are illustrated Figure 3.10. The average day demand projection (meter-based) most closely follows the medium growth projection from the 2013 WDA. The maximum day demand projection (meter-based) falls within the low growth projection range through 2045.

The City also developed an average day water demand projection as part of the 2015 Water Resources Plan and includes a 1 percent drought and targets a 0.35 percent conservation effort through year 2060. In 2014, the City decided on a 1 percent drought tolerance to provide greater water supply resiliency. Water conservation is also part of the City's long term strategy to reduce the need for a new water supply source. Additionally, conservation efforts have reduced the base demand over the last 5 years as stated in the Water Resources Plan. Applying a constant maximum day to average day factor of 1.80 throughout the planning period is representative of the meter-based water demand projection. The average day and maximum day demand projections developed in the Water Resources Plan are listed below, listed in Table 3.6, and illustrated in Figure 3.10:

- 2016 at approximately 66 MGD and 118 MGD respectively.
- 2020 at approximately 67 MGD and 120 MGD respectively.
- 2035 at approximately 70 MGD and 127 MGD respectively.
- 2045 at approximately 71 MGD and 128 MGD respectively.
- For information only, in 2060 at approximately 72 MGD and 129 MGD respectively.

The meter-based average day and maximum day demand projections by planning period are summarized below for comparison to the Water Resources Plan projections:

- 2016 at approximately 62 MGD and 114 MGD respectively.
- 2020 at approximately 63 MGD and 115 MGD respectively.
- 2035 at approximately 70 MGD and 125 MGD respectively.
- 2045 at approximately 75 MGD and 129 MGD respectively.

After review of the meter-based water demand projections and comparison with the Water Resources Plan, City staff concludes the projections from Water Resources Plan are adequate for the hydraulic modeling and evaluation for the development of capital improvements in this Water Master Plan.

* * * * *

4.0 EXISTING WATER SYSTEM

This section of the report provides background and general description of key features in the raw water system and the potable water distribution system incorporated in each hydraulic model. For clarity, capacity and treatment process information regarding the Main WTP is for general reporting purposes; the WTP is not incorporated in the hydraulic model. The raw water model includes multiple groundwater supply sources, surface water supply, and transmission to WTP influent piping and valving. The water distribution system model includes high service pumping, booster pumping, system storage, and the distribution system pipe network that delivers water to the City's retail and wholesale customers. The raw water and water distribution systems are illustrated in Figure 4.1.

4.1 Raw Water System

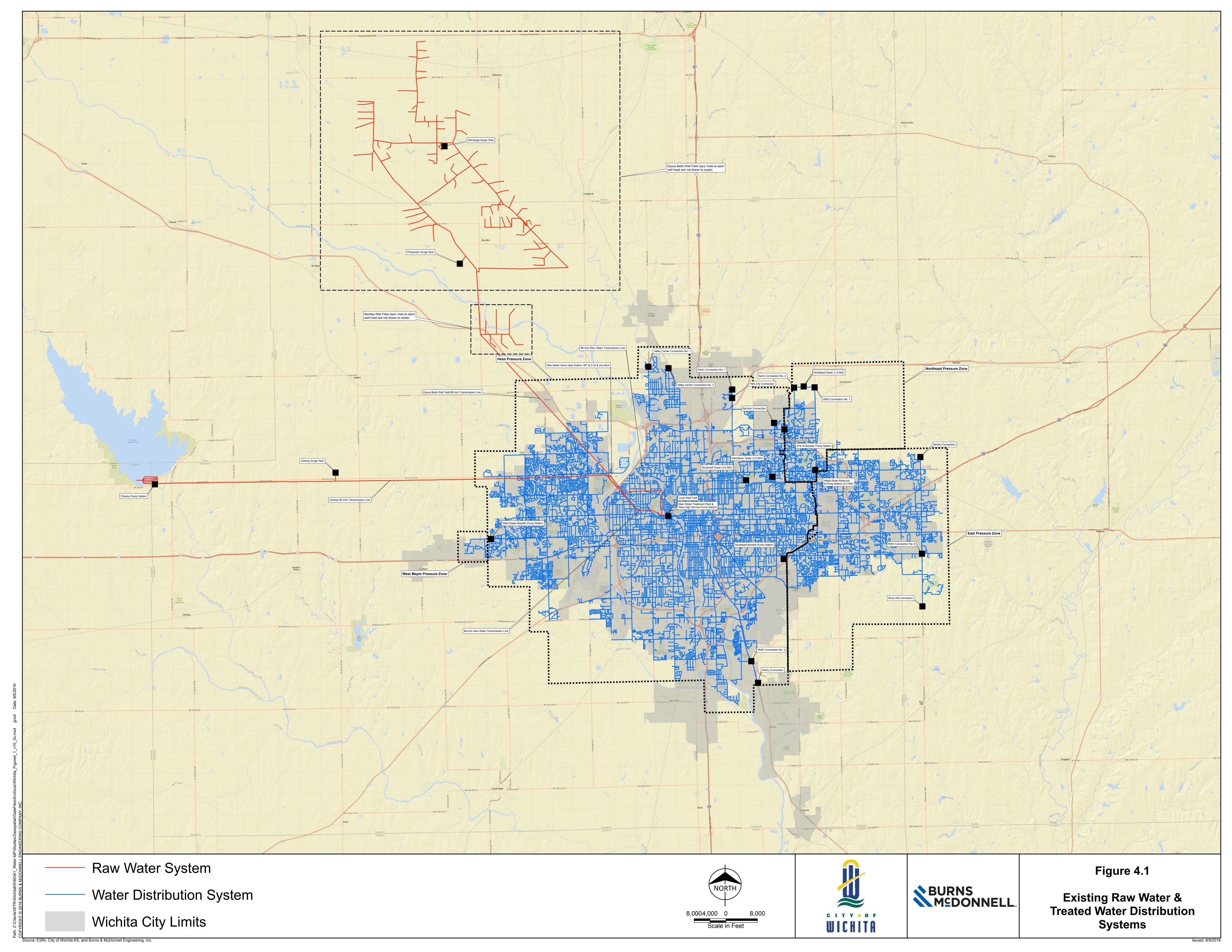
The City of Wichita has four sources of water supply, Cheney Reservoir, Equus Beds Well Field (EBWF), Bentley Well Field, and the Local Well Field, as shown in Figure 4.2. These sources are utilized as an integrated raw water supply in order to preserve the individual capacity and quality of each raw water resource. Cheney Reservoir is a primary raw water source and is located about 20 miles west of Wichita and typically provides a majority of annual supply. The EBWF includes 64 wells located about begins about 16 miles northwest of downtown Wichita, and is the other primary raw water supply for the City. The Bentley Well Field was redeveloped in 2009 to capture water from the Arkansas River during high flow periods, and includes a total of six wells. The local well field, also known as the E-Wells and S-Wells, surround the WTP and are primarily used to meet peak water demands.

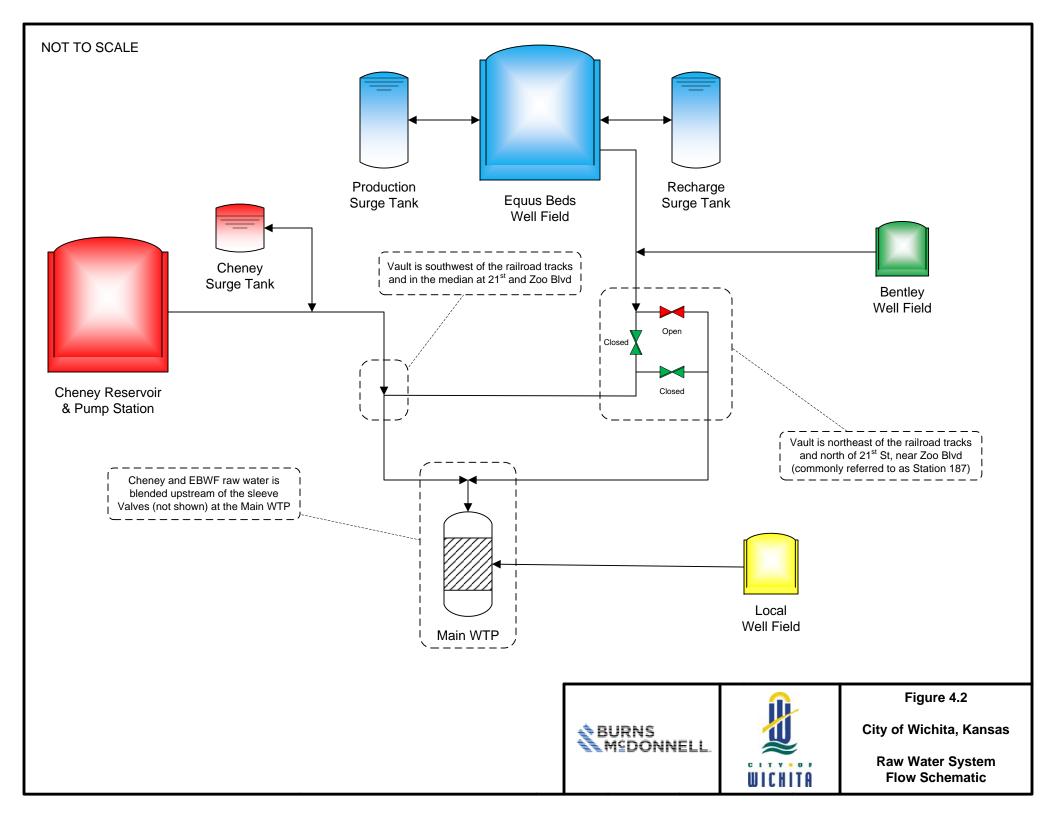
4.1.1 Cheney Reservoir

Cheney Reservoir was completed in 1965 and has a firm yield of about 49,000 acre-feet per year (AFY) or 43.7 million gallons per day (MGD). The reservoir has 151,780 acre-feet of storage capacity in the conservation pool. Cheney pump station has a firm pumping capacity of about 80 MGD; however, pumping is currently limited to approximately 68 MGD in the 60-inch transmission pipeline. Field testing conducted in 2007 concluded air pockets in the transmission pipeline are the limiting factor in delivering more than 68 MGD. Additional air release valves and changes to operation of the pipeline are required to increase the capacity to 80 MGD.

Wichita has three water rights for Cheney Reservoir as detailed below:

 Water Right 5033 allows for 30,667 acre-feet of water per year at a maximum diversion rate of 60 MGD.





- Water Right 40126 allows for an additional 21,973 acre-feet of water per year at a maximum rate of 60 MGD.
- These combined water rights limited Wichita to 52,640 acre-feet per year, (a distributed daily use of 47 MGD), and a maximum additional withdrawal rate of 120 MGD.
- In the late 1990's, Wichita received Water Right 42824 that changed the annual withdrawal to the summation of Cheney and the EBWF at 98,638 acre-feet per year or a distributed daily quantity of 82.7 MGD. This water right facilitated access to an additional 36,000 acre-feet when water levels in the reservoir exceed 1,420 feet above mean sea level. The maximum diversion rate from the reservoir was limited to 120 MGD. This water right allows the City to manage and maximize the use of surface water during times of surplus, ultimately maintaining firm supply and the superior water quality from the EBWF.

Algal blooms have been an operational issue with the reservoir since the early 1990's. Wichita initiated watershed protection efforts in partnership with Cheney Lake Watershed, Inc. in 1994 to protect the lake water quality and reduce the need for advanced treatment requirements at the WTP. Implementation of best management practices substantially reduced the inflow of agricultural nitrogen and phosphorus discharge into the reservoir and dampen the impact of algal blooms. Algal blooms periodically reoccurred in late 2002 through 2003 causing episodes of taste and odor in the potable water, therefore, the City initiated a taste and odor study in spring 2003 and installed an ozone feed system in 2005. Ozone was originally dosed between 4 to 5 mg/L until bromate formation was discovered. Ozone was recently modified to reduce chemical cost and maximize treatment benefits without overfeeding, in addition to limiting bromate formation potential. Ozone dose should be adjusted when events with high TOC and color are present, elevated 2-methylisoborneol (MIB) or geosmin levels, events with cell counts that trigger KDHE warning, or elevated algal toxins.

In June of 2016, cyanobacteria cell count in Cheney Reservoir was found to be higher than what is typically observed. In the southwest end of the reservoir, cell counts reached 363,000 cells/mL. Other areas ranged between 45,000 and 100,000 cells/mL. Water quality testing showed that the cyanobacteria were producing taste and odor compounds and algal toxins. The compounds most commonly associated with taste and odor episodes are geosmin and MIB. Geosmin, which literally translates to "earth smell," is an organic compound with a distinct earthy flavor and aroma. Ozone at Cheney Reservoir was increased from 2.0 to 3.5 mg/L to better treat the algal blooms.

Cyanobacteria produce a chemically and bioactively diverse group of toxins. Some of these compounds are very toxic and could pose a health risk to people and animals when they are exposed to them in large enough quantities. KDHE and the City of Wichita conducted periodic testing for cell count, cell ID, Geosmin, and various algal toxins. High cell counts that occurred during first half of June placed Cheney Reservoir on the KDHE "Warning List". Microcystin concentrations were low and ranged between 2 and 4 µg/L. Other species, including cylindrospermopsin, anatoxin, and saxitoxin were not detected.

During the last week of June 2016, cell counts declined, but microcystin concentrations increased to between 4 and 5 μ g/L, which put Cheney Reservoir on KDHE's "Watch List". After treatment, finished water samples were non-detect (less than 0.3 μ g/L).

4.1.2 Equus Beds Well Field

The City of Wichita and several other users including industrial, agricultural, domestic, and other municipalities have been using the aquifer water since 1939. Since the 1970's, over-development of the Equus Beds Aquifer has continued to occur and, as a result, groundwater levels declined substantially through 1993. In addition to declining groundwater levels, the gradient created by these declining groundwater levels caused natural chloride contamination from the Arkansas River and chloride contamination from the abandoned Burrton oil field to be pulled toward the EBWF at an accelerated rate threatening to degrade the generally high quality of the EBWF. Wichita maintains three senior water rights within the EBWF, HV006, 00388, and 1006, with a combined total access to 40,000 acre-feet per year, at a maximum withdrawal rate of 78 MGD.

Wichita City Council adopted the Integrated Local Water Supply Plan (ILWSP) in 1993 and has implemented the following portions:

- Increased focus on surplus surface water supplies
 - o Implement Cheney Reservoir as a primary and preferred resource.
 - o Implement an Aquifer Storage and Recovery (ASR) Project in the EBWF with above-base flow from the Little Arkansas River
- Redevelop the Bentley Reserve Well Field.
- Expand the Local Well Field.
- Continue demand management practices.

Development of the EBWF has been ongoing since 1939 and a general timeline summary is listed below:

• Originally developed wells in 1939 with a total of 25 wells.

- Additional 10 wells added in 1949.
- Additional 20 wells added in 1958.
- ASR Phase 1 included three diversion wells, one Recharge Well (RW), three Recharge Recovery
 Wells (RRW), one recharge basin; work was completed in 2007 with the primary purpose of
 developing a hydraulic resistance to the nearby Burrton chloride contamination.
- ASR Phase 2 was completed in 2013 with the purpose of expanding recharge facilities and replacing aging infrastructure including the following:
 - o Replaced 14 production wells with RRWs.
 - o Added six new RRWs at new locations within the EBWF.
 - Installed one additional RW
 - Expanded a recharge basin at an existing site (RB36).
 - Replaced about 28 miles of raw water pipeline to provide 146 MGD of raw water supply from the EBWF.

4.1.3 Bentley Well Field

The Bentley Well Field was redeveloped in 2009 and installed six wells along the Arkansas River south of the EBWF. Two of the wells have a groundwater right and the other four wells are used for bank storage and initiate operation at a minimum streamflow of 165 cubic feet per section (cfs). The well field has a total combined water right of 2,861 acre-feet at a maximum diversion rate of 13.8 MGD.

Water quality from the Bentley Well Field can be an issue as the Arkansas River is naturally high in chlorides. Chloride concentrations in the river and local aquifer tend to decrease as streamflow increases and the City strives to limit chlorides to 200 mg/L in the finished water; therefore, water is pumped from the Bentley Well Field to the WTP based on the anticipated raw water quality, and the ability to blend the chlorides with the other water sources.

4.1.4 Local Well Field

The LWF includes 16 wells originally constructed in 1949 and expanded in 1953. Four wells were redrilled in 1997 and 6 wells were redrilled in 2012. These wells are adjacent to the WTP between the Arkansas River and Little Arkansas River. The existing LWF has five water rights. The S-Wells are authorized by four water rights that combine for 1,120 acre-feet per year (SG-1, 42879, 42880, and 42881) at maximum diversion rate of 22.3 MGD. The remaining water right (540) authorizes the E-wells at 16,440 acre-feet per year at a maximum diversion rate of 14.6 MGD. These wells allow for a distributed average withdrawal of 15.67 MGD and a maximum withdrawal rate of 37 MGD. Historical

operation shows these wells can effectively pump about 30 MGD for a few weeks then aquifer yield decreases to a range of 15 to 18 MGD depending on river stage.

4.1.5 Total Raw Water Supply Capacity

Wichita's current water rights total 113,059 acre-feet per year from the four existing water sources as shown in Table 4.1. This equates to an average day of 101 MGD; the total maximum allowable permitted diversion rate is 170.8 MGD. Based on these water right capacities and the projected demand, no additional water rights are required to meet demands through 2050; however, the system is not completely drought-proof. Recharge of the EBWF was the planned mechanism to minimize risk of a water short-fall for the City and their customers.

4.2 Water Distribution System

The Main WTP includes the East and Central treatment trains and is located on the north bank of the Arkansas River, just upstream of the confluence of the Little Arkansas River near Museum Boulevard. Treated potable water is stored in the Hess Reservoir system and pumped to the distribution system by Hess HSPS. The water distribution system includes Hess, East, West Maple, and Northeast pressure zones where water is either boosted directly from Hess pressure zone or held in ground storage and pumped. Elevated storage in the distribution system is primarily relied on for system control and some equalization demands; it is not relied on for fire or emergency service. The modeled distribution system is illustrated in Figure 4.3 and includes water mains greater than or equal to 8-inches in diameter made available from the City's water system GIS in January 2016. The hydraulic model also includes some smaller diameter mains where the piping is deemed hydraulically necessary for distribution system connectivity.

4.2.1 Production & High Service Pumping

The Main WTP currently treats a blend of raw surface water from Cheney Reservoir and groundwater predominantly from the EBWF. The Main WTP includes two treatment trains, also referred to as the Central WTP and East WTP, with a total rated capacity of 160 MGD. The design capacity of the Central WTP is 130 MGD. The design capacity of the East WTP is 30 MGD and is typically used in conjunction with the Central WTP during periods of high demand or during periods of maintenance outages in the Central WTP. The combined operational capacity of the Central and East WTPs is less than 160 MGD and potentially limited by hydraulic bottlenecks, backwashing capability, and/or filter loading.

Hess HSPS delivers water from the Hess Reservoir system to the distribution system from a combination of eight pumps with varying sizes. The firm capacity is approximately 202 MGD at approximately 264 ft

Table 4.1 Water Rights Summary

Raw Water Source	Water Right	Maximum Quantity	Average Daily	Maximum Diversion	*Limitation
Naw Water Source	Designation Number	Acre-Feet/Year	Diversion (MGD)	Rate (MGD)	Description
	5033	30,667	27.4	60.0	
Cheney Reservoir	40126	21,973	19.6	60.0	
	5033 & 40126 Combined	52,640	47.0	120.0	
EBWF + Cheney Conjunctive Use	42824*	36,000	32.1	80.0	Conjunctive Use, available above 1,420' MSL.
	Allowable Maximum:	88,640		120.0	
	HV006	25,000	22.3	33.0	
EBWF	388	40,000	35.7	48.0	-
	1006	25,000	22.3	30.0	Limited to a Maximum of 40,000 AF at a maximum
	Allowable Maximum:	40,000	35.7	78.0	diversion rate of 78MGD.
Cheney + EBWF Maximum Allowabl	e Conjuctive Use	92,638	82.7	120.0	
	\$G-1	1,120	1.0	18.1	Tied to EBWF water right 1006. ¹
Local Well Field (S-wells)	SG-1 42879	1,120 131	1.0 0.1	18.1 1.4	
Local Well Field (S-wells)		·		1.4 1.4	No additional quantity from 42879, 42880, and
Local Well Field (S-wells)	42879	131	0.1	1.4	
Local Well Field (S-wells) Local Well Field (E-wells)	42879 42880	131 130	0.1 0.1	1.4 1.4	No additional quantity from 42879, 42880, and
, ,	42879 42880 42881	131 130 130	0.1 0.1 0.1	1.4 1.4 1.4	No additional quantity from 42879, 42880, and 42881, only additional rate.
, ,	42879 42880 42881 540	131 130 130 16,440	0.1 0.1 0.1 14.7	1.4 1.4 1.4 14.6	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. ¹
, ,	42879 42880 42881 540	131 130 130 16,440	0.1 0.1 0.1 14.7	1.4 1.4 1.4 14.6	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. ¹
. ,	42879 42880 42881 540 Allowable Maximum:	131 130 130 16,440 17,560	0.1 0.1 0.1 14.7	1.4 1.4 1.4 14.6 36.9	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. ¹
Local Well Field (E-wells)	42879 42880 42881 540 Allowable Maximum:	131 130 130 16,440 17,560	0.1 0.1 0.1 14.7	1.4 1.4 1.4 14.6 36.9	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. ¹
Local Well Field (E-wells)	42879 42880 42881 540 Allowable Maximum:	131 130 130 16,440 17,560	0.1 0.1 0.1 14.7 0.3 0.5	1.4 1.4 1.4 14.6 36.9	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. ¹ Groundwater Permit
, ,	42879 42880 42881 540 Allowable Maximum: 45297 45296 45298	131 130 130 16,440 17,560 331 506 506	0.1 0.1 0.1 14.7 0.3 0.5 0.5	1.4 1.4 1.4 14.6 36.9	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. ¹ Groundwater Permit
Local Well Field (E-wells)	42879 42880 42881 540 Allowable Maximum: 45297 45296 45298 45299	131 130 130 16,440 17,560 331 506 506 506	0.1 0.1 0.1 14.7 0.3 0.5 0.5 0.5	1.4 1.4 1.4 14.6 36.9	No additional quantity from 42879, 42880, and 42881, only additional rate. Tied to EBWF water right 1006. Groundwater Permit Conditional to Arkansas River conditions exceeding

Total Raw Water Allowable Maximum

113,059

98

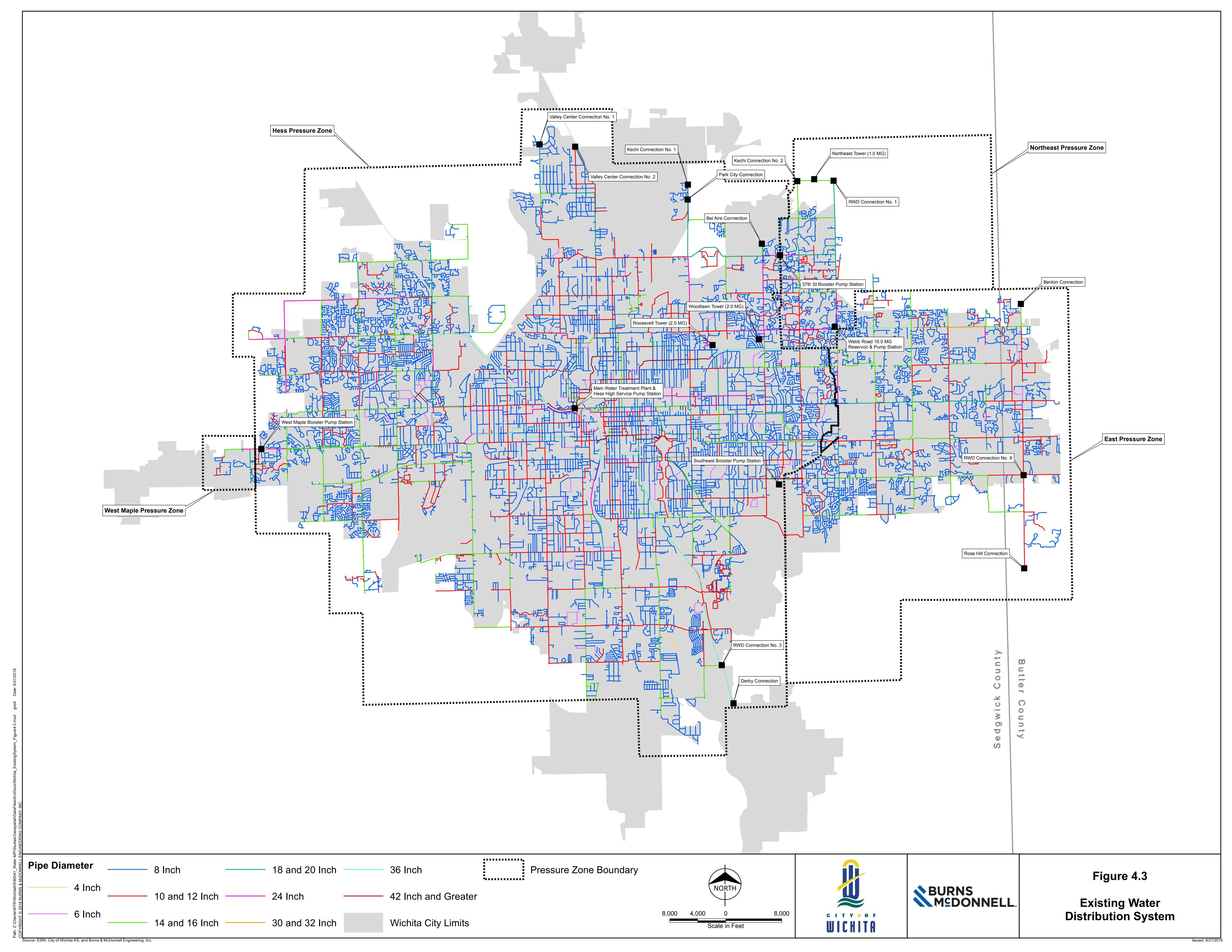
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Notes:

1. Limitation and/or relationship may require addition investigation.

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of pump head with the largest pump out of service. Pump curve information and manufacturer's information for the Hess high service pumps are listed in Table 4.2.

4.2.2 Pressure Zone Relationship

The water distribution system includes four pressure zones. Hess pressure zone is the primary pressure zone that conveys water to the East, West Maple, and Northeast pressure zones. Even though elevated storage exists in the Hess and Northeast pressure zones, the City operates them like a closed system. By traditional definition, a closed system is a pressurized network with no elevated storage. A pressurized network with active and effective elevated storage is considered an open system. The East and West Maple pressure zones function and operate like a traditional closed system. A description of the pressure zone relationship described in the following sections is illustrated in Figure 4.4.

A more in depth discussion on effective storage, for both ground and elevated storage, is provided in the storage evaluation within Section 6.0 of this report. A general description of the operational controls and parameters is provided in Appendix A and includes meeting minutes from interviews conducted with City staff tasked responsible for the pumping and storage components of the water distribution system.

4.2.2.1 Hess Pressure Zone

In terms of customers, demand, and pipe network size in terms of linear feet, Hess pressure zone is by far the largest pressure zone. In 2015, Hess pressure zone represented approximately 78 percent (36.7 MGD) of the average day demand in the entire distribution system. Water demand is supplied by the Hess Reservoir and HSPS, Woodlawn Tower, and Roosevelt Tower. Elevated storage from the towers is primarily used for operational control by operators. Hess HSPS also pumps water to the Webb Road Reservoir. Webb Road Reservoir is used as a storage buffering mechanism for the entire distribution system, but only to the extent made possible from the turnover volume imparted by the pumping operations and water demand in the Northeast pressure zone.

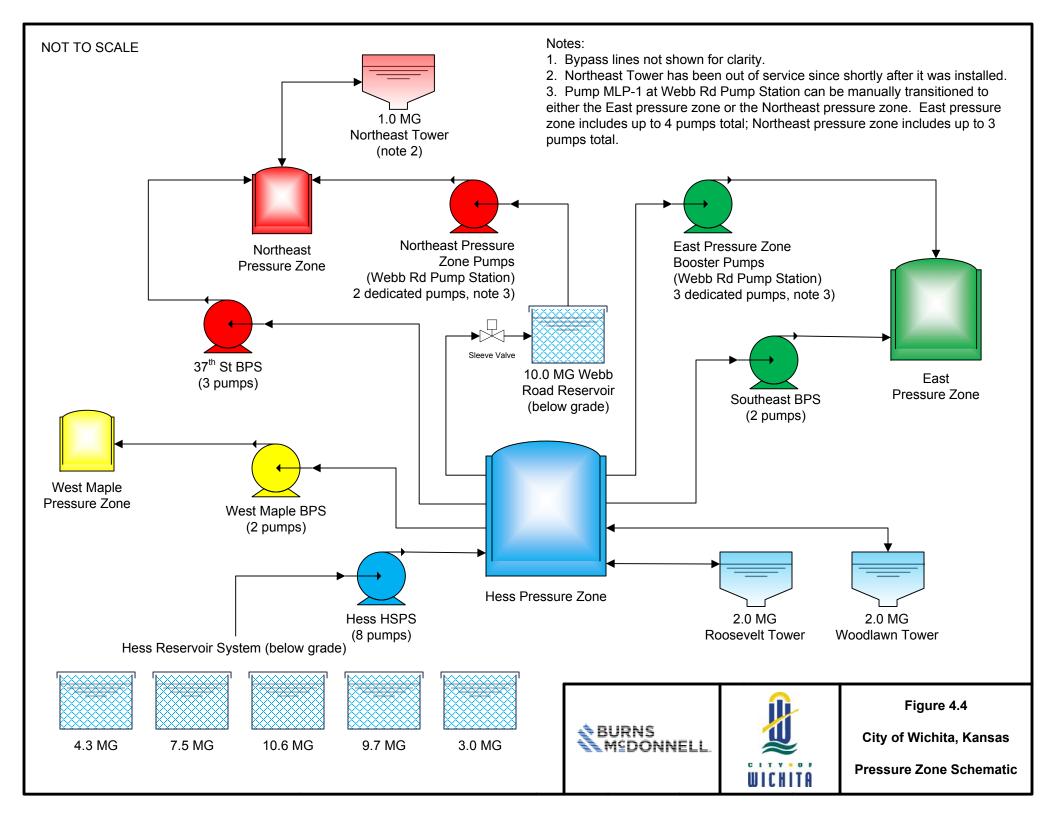
4.2.2.2 Northeast Pressure Zone

The Northeast pressure zone represented approximately 7 percent (3.5 MGD) of the total average day demand in 2015. Water demand is supplied by the Webb Road Reservoir and PS and the 37th Street BPS. Webb Road Reservoir is below grade and filled by the Hess pressure zone through a sleeve valve. The sleeve valve maintains an inlet pressure to sustain the hydraulic gradient in the Hess pressure zone and permit flow into the reservoir. The Webb Road Reservoir is dedicated storage for the Northeast pressure zone and is pumped by a combination of as many three pumps at Webb Road PS. One of the pumps provides transitional pressure zone service to either the Northeast or East pressure zone by opening and

Table 4.2
Hess High Service Pump Station Information

		ŀ	lead-Capacity Curv	e Data		
		Rated D	uty Point	End of Pub	ished Curve	Dump Efficiency @
Pump No.	Shutoff Head (ft)	Flow (MGD)	Head (ft)	Flow (MGD)	Head (ft)	Pump Efficiency @ Duty Point (%)
1	355	28.8	300	40.3	200	86
2	355	28.8	300	40.3	200	86
3	370	36.0	264	56.0	200	85
4	355	28.8	302	38.9	225	87
5	305	25.2	264	34.6	190	86
6	370	36.0	264	56.0	200	85
7	305	25.2	264	34.6	190	85
8	355	28.8	300	40.3	200	86
		Ad	ditional Pump Info	rmation		
Pump No.	Manufacturer	Horsepower	Speed	Driver	Dedicated	VFD
		(hp)	(rpm)		VFD	Capability
1	Patterson	1820	900	constant	no	yes
2	Patterson	1820	900	VFD	yes	yes
3	Patterson	1855	900	constant	no	yes
4	Patterson	1855	900	constant	no	yes
5	Patterson	1820	900	constant	no	yes
6	Patterson	1855	900	constant	no	yes
7	Patterson	1750	900	constant	no	yes
8	Patterson	1820	900	constant	no	yes

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closing multiple valves positioned in the suction and discharge headers; the other two pumps are dedicated to the Northeast pressure zone. Transitional pumping service is done locally and manually by City staff at Webb Road PS.

The 37th Street BPS takes direct suction from the Hess pressure zone and also serves the Northeast pressure zone. The Northeast pressure zone includes elevated storage in the Northeast Tower, but it was taken out of service in 2012; therefore, this pressure zone is operated as a closed system.

4.2.2.3 East Pressure Zone

The East pressure zone represented approximately 15 percent (6.8 MGD) of the total average day demand in 2015. Water demand is supplied by the Webb Road PS to the East pressure zone from a combination of as many as four pumps. These pumps provide booster service and take suction directly from the Hess pressure zone. As indicated above, one of the pumps provides transitional pressure zone service to either the Northeast or East pressure zone by opening and closing multiple valves positioned in the suction and discharge headers; the other three pumps are dedicated to the East pressure zone. Water demand is also supplied by the Southeast BPS and also takes direct suction from the Hess pressure zone.

4.2.2.4 West Maple Pressure Zone

The West Maple pressure zone includes a small number of residential customers, two elementary schools, one middle school, and one high school whose 2015 average day demand was approximately 45 gpm.

The Maple BPS takes direct suction from the Hess pressure zone and serves the West Maple BPS.

4.2.3 Booster Pumping

Distribution system pump stations include Webb Road PS and 37th Street BPS which serve the Northeast pressure zone, Webb Road PS and Southeast BPS which serve the East pressure zone, and the West Maple BPS which serves the West Maple BPS. Pump curve and manufacturers information for distribution system pumping is listed in Table 4.3.

4.2.4 Pipe Metrics

The water distribution system piping, as modelled, includes approximately 1,790 miles from a combination of ductile iron pipe (DIP), PVC, HDPE, asbestos cement, cast iron, and galvanized pipe. The hydraulic model was developed from the City's water system GIS and includes pipes greater than or equal to 8-inches in diameter and some smaller sizes where distribution system connectivity necessitated their inclusion. The 6-inch, 8-inch, and 12-inch diameter pipes represent approximately 89 percent of the

Table 4.3
Distribution System Pump Data

		Web	b Road Pump Curv	e Data		
		Rated D	uty Point	End of Publ	ished Curve	Pump Efficiency @
Pump No.	Shutoff Head (ft)	Flow (MGD)	Head (ft)	Flow (MGD)	Head (ft)	Duty Point (%)
BDP-2	224	3.0	190	4.4	122	note 1
BDP-3	243	5.0	200	8.9	143	note 1
MLP-1	259	5.0	192	6.8	140	87
MLP-2	76	12.5	50	16.6	30	86
MLP-3	76	12.5	50	16.6	30	86
MLP-4	76	12.5	50	16.6	30	86
		Add	itional Pump Inforr	mation		
Pump No.	Manufacturer	Horsepower (hp)	Speed (rpm)	Driver	Pressure Zone Service	VFD Capability
BDP-2	Aurora	150	note 1	Constant	Northeast	no
BDP-3	Aurora	300	note 1	VFD	Northeast	yes
MLP-1	Aurora	250	1800	Constant	Northeast, East	no
MLP-2	Aurora	150	900	VFD	East	yes
MLP-3	Aurora	150	900	VFD	East	yes
MLP-4	Aurora	150	900	VFD	East	yes

		37th S	treet BPS Pump Cu	irve Data		
		Rated Di	uty Point	End of Pub	ished Curve	Duman Efficience: @
Pump No.	Shutoff Head (ft)	Flow (MGD)	Head (ft)	Flow (MGD)	Head (ft)	Pump Efficiency @ Duty Point (%)
1	293	2.6	231	3.5	162	note 1
2	127	0.6	120	1.3	60	note 1
3	127	2.2	120	3.7	69	note 1
		Add	itional Pump Infor	mation		
Pump No.	Manufacturer	Horsepower (hp)	Speed (rpm)	Driver	Pressure Zone Service	VFD Capability
1	note 1	note 1	note 1	VFD	Northeast	yes
2	note 1	note 1	note 1	Constant	Northeast	no
3	note 1	note 1	note 1	Constant	Northeast	no

	Southeast BPS Pump Curve Data											
		Rated Di	ıty Point	End of Publ	ished Curve	D F#:-:						
Pump No.	Shutoff Head (ft)	Flow (MGD)	Head (ft)	Flow (MGD)	Head (ft)	Pump Efficiency @ Duty Point (%)						
1	285	12.0	130	14.8	115	87						
2	285	12.0	130	14.8	115	87						
		Add	itional Pump Infor	mation								
Pump No.	Manufacturer	Horsepower (hp)	Speed (rpm)	Driver	Driver Pressure Zone Service							
1	Wemco	350	1190	Constant	East	no						
2	Wemco	350	1190	Constant	East	no						

		West I	Maple BPS Pump Cu	ırve Data		
		Rated D	uty Point	End of Pub	lished Curve	D F#:-: @
Pump No.	Shutoff Head (ft)	Flow (MGD)	Head (ft)	Flow (MGD)	Head (ft)	Pump Efficiency @ Duty Point (%)
1	232	0.8	111	0.9	40	62
2	232	0.8	111	0.9	40	62
		Add	itional Pump Infori	mation		
Pump No.	Horsepower Speed Pressure					
1	Grundfos	note 1	note 1	VFD	West Maple	yes
2	Grundfos	note 1	note 1	VFD	West Maple	yes

Notes:

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^{1.} Information unknown; information that is listed is the best available data provided by the City.

modelled distribution system with 8-inch being the largest in overall linear feet at approximately 1,200 miles or approximately 67 percent of the modelled distribution system.

4.2.5 Storage

Ground storage includes the Hess Reservoir system, which provides storage for the entire distribution system, and Webb Road Reservoir which provides dedicated storage for the Northeast pressure zone. Elevated storage includes the Roosevelt and Woodlawn towers located in the Hess pressure zone and the Northeast Tower located in the Northeast pressure zone. Ground and elevated storage details are listed in Table 4.4.

As indicated previously, even though Hess pressure zone includes elevated storage in the Roosevelt and Woodlawn towers, it is operated like a closed system. Tower level is controlled manually by City staff from the Main WTP control room. A butterfly valve, at each tower, is actuated to control the drafting and filling status above a predetermined water level elevation, or hydraulic gradient, which maintains a designated minimum pressure in the Hess pressure zone. The low level alarm is set at 22 feet which is equivalent to a hydraulic gradient of 1,504 ft and is also equivalent to approximately 63 percent of the volume in each tower. The head range of each tower is 35 feet, and, generally speaking, tower level is controlled between 28 ft and 32 ft.

The Northeast Tower has been out of service since 2012. When the tower was in service, City staff reported an inability to adequately turnover the tank volume which resulted in insufficient water quality due to high water age. Additionally, the Webb Reservoir PS and 37th Street BPS control philosophies were not modified to support the operational shift from a closed system to an open system.

* * * * *

Table 4.4 Storage Summary

Name	Pressure Zone	Туре	Capacity (MG)	Finished Floor Elevation ¹ (ft)	Overflow Elevation (ft)	Head Range (ft)
Roosevelt Tower	Hess	elevated	2.0	1,402	1,517	35
Woodlawn Tower	Hess	elevated	2.0	1,412	1,517	35
Northeast Tower	Northeast	elevated	1.0	1,412	1,580	40
Hess Reservoir	all	ground	10.6	1,287	1,302	15
Hess Reservoir	all	ground	9.7	1,287	1,302	15
Hess Reservoir	all	ground	7.5	1,287	1,302	15
Hess Reservoir	all	ground	4.3	1,287	1,302	15
Hess Reservoir	all	ground	3.0	1,287	1,302	15
Webb Reservoir	Northeast	ground	10.0	1,375	1,395	20

Notes:

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^{1.} Finished floor elevations listed for Roosevelt and Woodlawn towers represent grade elevations.

5.0 DISTRIBUTION SYSTEM MODEL CALIBRATION

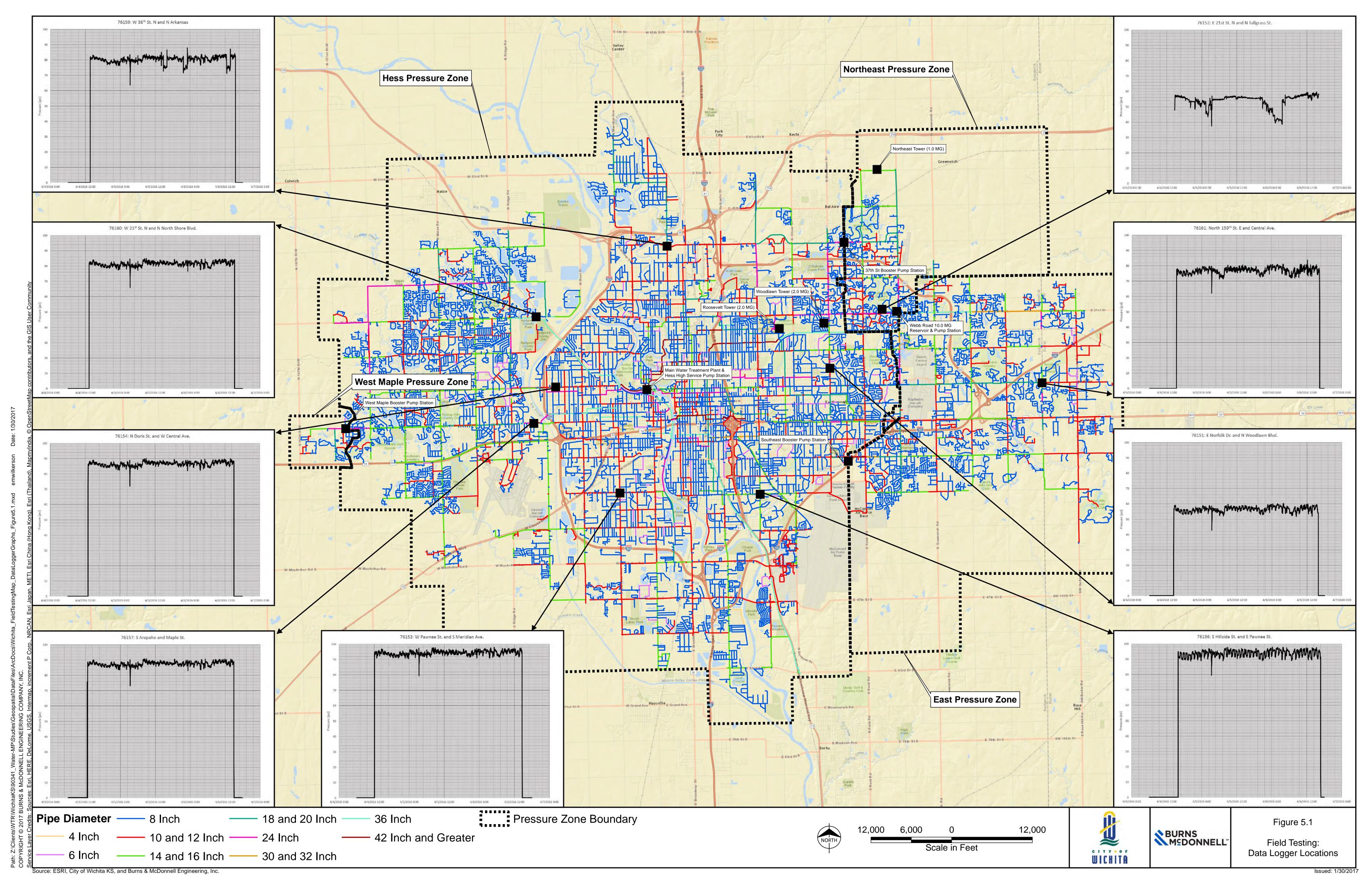
This section of the report discusses the field testing program, model calibration verification, hydraulic analysis criteria, and the diurnal analysis of the Wichita water distribution system.

5.1 Field Testing and Data Collection

Field testing was conducted, from April 4, 2016 through April 11, 2016, to collect data to verify model calibration. Field testing activities included fire hydrant tests and pressure monitoring in the distribution system recorded by data loggers. Data loggers were positioned on fire hydrants located at or near water mains ranging between 8 inches and 12 inches in diameter and are shown in Figure 5.1. Supervisory Control and Data Acquisition (SCADA) historian information was collected for distribution facilities to complete the data set required for verification of the model calibration are listed below:

- Pumping at Hess HSPS, Webb Road PS, Southeast BPS, 37th Street BPS, and West Maple BPS
 - Suction and discharge pressure
 - o Flow
 - VFD speed where applicable
 - Bypass status where applicable
- Storage levels at Woodlawn Tower, Roosevelt Tower, and Webb Reservoir
- Pressure in Hess pressure zone at:
 - o 47th and West Street
 - o 13th and Tyler
 - o Central and Main
- Pressure in the East pressure zone at:
 - Kellogg and Webb
 - o Harry and Webb
- Pressure in the Northeast pressure zone at:
 - o 34th and Webb
- Pressure in the West Maple pressure zone at:
 - o 167th St and West Maple

Fire hydrant testing was conducted at 33 locations in the distribution system on April 4th and 5th, 2016. Fire hydrant testing simulates hydraulic stress in the distribution system and the test results are used to confirm the calibration of the hydraulic model. The procedure includes discharging water from a hydrant, termed as the "flowing" hydrant, and observing the corresponding pressure drop in the system at an



adjacent hydrant in the vicinity, termed as the "gauged" hydrant. The rate of flow discharged from the flowing hydrant is calculated based on the residual pressure. City staff were present at all fire hydrant testing locations and the results are included in Appendix B.

5.2 Model Calibration Verification

Calibration is performed by adjusting, if needed, the Hazen-Williams coefficient, or C-value, assigned to pipe segments to simulate pressure recorded from fire hydrant tests and from data logger under static and flowing conditions. The C-values are adjusted in the model within 5 psi of the field test results up to a pressure of 80 psi; above 80 psi, the C-values are adjusted to simulate field conditions within 10 percent. The C-values assigned in the model represent the relative internal roughness and provide an indication of the degree of roughness within a pipe. Pipes with high C-values convey water with little frictional headloss, but C-values generally decrease with age. Pipes with low C-values can be indicative of partially closed valves in the distribution system, scaling, or other water quality issues. When C-values degrade beyond a certain point, pipe replacement should be considered.

The model developed in the previous water master plan, dated 2006, included all pipes greater than or equal to 12-inches in diameter and other smaller diameters where the distribution system connectivity was required. This model is updated with the City's current water system GIS information and now includes all pipes greater than or equal to 8-inches in diameter and some smaller pipes for system connectivity. The following C-values are assigned to the additional pipes (8-inch and 10-inch) included in the model update:

- Asbestos cement = 115
- Cast iron = 105
- Ductile iron = 125
- PVC = 130
- HDPE = 130

Model calibration results are listed in Tables 5.1 and 5.2 and validate the C-values applied to the distribution system. Table 5.1 represents the fire hydrants tests paired with the Burns and McDonnell data logger locations and Table 5.2 represents the fire hydrant tests paired with the City's SCADA system pressure monitoring locations. The model calibration adequately represents fire hydrant test results at the gauged hydrant for the system demands experienced during field testing. The model calibration also adequately represents the pressures recorded in the distribution system at data logger locations within 5

Table 5.2
Water Distribution System Calibration - City Data Logger Locations

					City SCADA Syst	em Pressure Mon	itoring Locations		
Fire Hydrant Test Location	Date	Time	167th St and Maple (psi)	13th St and Tyler (psi)	47th St and West St (psi)	Central and Main (psi)	34th St and Webb Rd (psi)	Kellogg and Webb Rd (psi)	Harry St and Webb Rd (psi)
A. Maxwell Field Data Model Results	4/5/2016	8:05:00 AM	58 58	68 68	97 98	94	50 54	62 60	47 63
B. West 35th St Field Data	4/5/2016	8:35:00 AM	61	68	99	93	53	61	47
Model Results C. Elder	4/5/2016	9:03:00 AM	57	67	96	93	54	59	63
Field Data Model Results			59 57	71 66	97 97	93 91	55 54	62 59	49 62
D. S. Turquoise Field Data	4/5/2016	9:27:00 AM	62	68	96	92	58	62	47
Model Results E. Grant St.	4/5/2016	9:49:00 AM	57	66	97	92	55	60	63
Field Data Model Results			60 57	70 67	99 98	91 93	58 60	62 61	49 65
F. N Parkridge St. Field Data	4/5/2016	10:13:00 AM	60	68	99	93	53	62	47
Model Results G. N. Shefferor	4/5/2016	10:30:00 AM	57	67	98	92	53	60	63
Field Data Model Results	. (= (=		61 57	70 66	97 97	92 92	56 52	62 61	48 64
H. N. Parkdale St. Field Data	4/5/2016	10:55:00 AM	62	70	98	92	56	62	47
Model Results I. Pepper Ridge	4/5/2016	11:16:00 AM	58	68 71	99	94	55	61	64
Field Data Model Results J. Barrington St.	4/5/2016	12:49:00 PM	61 58	67	98 98	93 93	56 55	61 60	48 64
Field Data Model Results	4/5/2016	12.49.00 PIVI	61 58	70 68	95 99	93 93	57 55	63 61	49 65
K. Harlan St. Field Data	4/5/2016	1:05:00 PM	62	69	98	91	53	60	48
Model Results L. Wellington	4/5/2016	1:38:00 PM	58	68	99	93	53	61	64
Field Data Model Results	1, 5, 2010	1.56.66 1 111	60 58	70 67	96 97	94 92	60 55	64 61	48 64
M. 47th St. Field Data	4/5/2016	2:01:00 PM	61	69	100	92	58	60	48
Model Results N. Ironwood St.	4/5/2016	2:31:00 PM	59	68	99	93	55	61	65
Field Data Model Results			61 59	70 69	97 100	92 94	51 50	62 62	49 65
O. Penstemmon Field Data	4/5/2016	2:54:00 PM	60	69	99	91	55	63	50
Model Results P. Winstead/E. 17th St	4/5/2016	3:21:00 PM	59	69	99	94	54	62	65
Field Data Model Results			60 59	70 68	99 98	92 93	58 55	60 61	48 64
Q. Battin St. Field Data	4/5/2016	3:49:00 PM	59	69	96	92	61	62	47
Model Results R. Erie Ave.	4/5/2016	4:20:00 PM	59	68	99	93	55	61	64
Field Data Model Results S. Williamsburg	4/F/204 <i>C</i>	4:44:00 PM	60 58	70 68	99 98	91 93	60 55	61 60	47 64
Field Data Model Results	4/5/2016	4:41:00 PM	60 60	69 68	97 98	92 93	57 55	59 60	45 63
T. Broadmoor Field Data	4/5/2016	5:06:00 PM	60	69	97	92	59	61	48
Model Results U. Woodridge Dr.	4/6/2016	8:33:00 AM	58	68	98	93	55	60	64
Field Data Model Results	1,0,2010	0.55.007111	62 58	69 68	98	93 94	61 70	59 59	45 62
V. Ayesbury St. Field Data	4/6/2016	8:54:00 PM	61	69	na	92	51	61	47
Model Results W. Sumac	4/6/2016	9:11:00 AM	58	67	98	93	65	59	63
Field Data Model Results			60 57	69 67	ND 97	94 92	52 63	61 59	48 62
Y. S. Lakeside Dr. Field Data	4/6/2016	9:43:00 AM	59	69	ND	93	54	64	45
Model Results Z. St. Andrew St.	4/6/2016	10:02:00 AM	58	68	98	93	65	60	63
Field Data Model Results			59 58	69 68	ND 98	94 93	55 66	65 60	50 64
AA. Linden St Field Data	4/6/2016	10:26:00 AM	61	70	ND	92	55	60	45
Model Results AB. Royal Dr.	4/6/2016	10:48:00 AM	56	66	96	92	57	58	61
Field Data Model Results			61 59	70 69	ND 99	94 94	59 60	63 62	49 65
AC. Vassar Field Data	4/6/2016	11:20:00 AM	61	70	ND OR	93	60	62	47
Model Results AD. Erie St. Field Data	4/6/2016	12:31:00 PM	59	68	98 ND	93	60	61	65
Field Data Model Results AE. Kinkaid	4/6/2016	12:55:00 PM	61 55	68 65	ND 95	91 90	60 54	60 58	46 62
Field Data Model Results	4/0/2016	12:35:00 PIVI	61 58	68 67	ND 97	92 92	60 55	62 60	47 64
AF. Maywood Field Data	4/6/2016	1:21:00 PM	60	70	ND	92	61	62	48
Model Results AG. W. 43rd St.	4/6/2016	1:44:00 PM	57	66	96	91	59	59	62
Field Data Model Results	1, 5, 2010	2.11.00 7 101	60 58	70 67	ND 95	93 93	60 60	62 60	48 64
AH. Martinson Field Data	4/6/2016	2:13:00 PM	61	71	ND	94	53	63	50
Model Results			59	68	98	93	58	61	65

City of Wichita, Kansas

psi up to a maximum recorded pressure of 80 psi and within 10 percent of the recorded pressure above 80 psi for the system demands experienced during field testing.

SCADA historian data for pressure at the intersection of Harry Street and Webb Road could not be used for calibration. On average, the model results for pressure are approximately 16 psi higher. Modelling efforts were conducted to determine if a potential cause was an open pressure zone valve, but the results did not reflect this condition in all calibration scenarios, but it does remain a viable explanation because of the calibration success for system pressure at the intersection of Kellogg Drive and Webb Road. This intersection is approximately 1 mile north of the intersection at Harry Street and Webb Road and there is only about 6 feet of elevation difference (from north to south). The model results for pressure at Kellogg and Webb are constantly within 1psi to 2 psi from the SCADA historian data. Potential causes for the difference between the model results and SCADA historian data for pressure at the intersection of Harry and Webb are:

- Open pressure zone boundary valve, or valves, south of Kellogg; or
- Inaccurate pressure readings; or
- Some combination of the conditions listed above.

The pressure variation between the model results and the SCADA historian data at Harry and Webb may also be related, but not attributed to, the pump station model adjustments made for model calibration with respect to the bypass line at Southeast BPS and is detailed in the following section.

5.3 Pump Station Model Adjustments for Model Calibration

The primary calibration focus is the pressure recorded by the data loggers and SCADA in the distribution system, and the gauged hydrant pressures (both static and while flowing). Matching pump station flow rates and corresponding suction and discharge pressures are also assessed and equally important, but are secondary in nature to distribution system pressure because it is a closed system and the control mechanism for all pumping and storage revolves around pressure at Central and Main. Maintaining a constant pressure, or range of pressures between 88 psi and 93 psi with a target pressure of 92 psi, at Central and Main effects how pumps are operated at Hess HSPS (i.e. speed, pump selection, Hess reservoir levels), tower levels, and sleeve valve position at Webb Road reservoir; these conditions then effect suction pressure at West Maple BPS, 37th Street BPS, Webb PS, and Southeast BPS which ultimately effect discharge pressure and flow into the pressure zones they serve.

Model results for flow, suction pressure, and discharge pressure are adequately represented at Hess HSPS and West Maple BPS with respect to SCADA historian data. Model results for flow and suction pressure

at 37th Street BPS and Webb Road PS (serving the Northeast pressure zone) are representative of SCADA historian data. Model results for the sleeve valve inlet pressure at Webb Reservoir and the bypass pressure at Webb Road PS (East pressure zone) and Southeast BPS are also representative of SCADA historian data. There are two conditions of note, where adjustments were made to simulate SCADA historian data, while complying with the primary calibration focus described in the previous paragraph, are listed below:

- Initial model results for discharge pressure at 37th Street BPS and Webb Road PS (serving the Northeast pressure zone) were high; approximately 10 psi to 20 psi higher at Webb Road PS and as much as 30 psi higher at 37th Street BPS compared to SCADA historian data.
 - This could be attributed to a shift in the pump curves, or a partially closed valve immediately downstream of the pump stations, or some other change.
- Initial model results for the flow split between the bypass lines at Southeast BPS and Webb Road PS (serving the East pressure zone) were approximately 50/50 and the SCADA historian data, on average, indicates approximately 91 percent is conveyed through the Webb Road PS bypass and the remaining 9 percent is conveyed through the Southeast BPS bypass.
 - This could be attributed to an open pressure zone boundary valve or multiple valves south of Kellogg, inaccurate flow meter readings at Southeast BPS, or reverse flow through the bypass line at Southeast BPS. The ball valves on each pump discharge header and the overpressure regulator valve were specified to prevent reverse flow. The bypass line includes an air/oil actuated butterfly valve that could allow reverse flow if Webb Road PS is in service. If the bypass lines at both pump stations are open, then system hydraulics, in theory, should prevent reverse flow because the hydraulic gradient is constantly falling from Hess pressure zone to the East pressure zone. For reference, the bypass line isolation butterfly valve should be closed if Southeast BPS is in service. Additional discussion on the intended control philosophy for the Southeast BPS is addressed in the future planning period sections of this report.

Model adjustments for calibration were made to simulate the conditions described above for Webb Road PS (serving the Northeast pressure zone, and the bypass lines at Webb Road PS (serving the East pressure zone) and at Southeast BPS, and are described below:

- Speed settings applied to the pumps at 37th St BPS and Webb Rd PS (Northeast PZ) to better match flow, discharge pressure, and pressure at 34th and Webb Rd.
- A constant minor loss coefficient was applied in each calibration scenario to the bypass line at Southeast BPS to force more flow through the Webb Road PS bypass line.

5.4 Hydraulic Analysis Criteria

Hydraulic analyses are conducted to determine the water distribution system's ability to deliver equalization storage, projected water demands, and identify deficiencies with respect to pipe capacity, pumping, pressure, and fire flow. The hydraulic analysis criteria used in the model and reported in this WMP include the following:

- Distribution system pressures are greater than 40 psi;
- Distribution system pressures are greater than 20 psi during fire flow analyses;
- HSPS firm capacity delivers the average demand on the maximum day at adequate pressure with the largest pump out of service;
- HSPS firm capacity provides peak hour assistance on the maximum day demand;
- Storage can be completely replenished over a 24-hour period and equalization storage replenished over an 8-hour period at night on a maximum day;
- Transmission pipeline velocities are less than 5 feet per second (fps), and head losses are less than 6 feet per 1,000 feet. Additional deficiencies to inadequate pipeline velocities and head losses, such as insufficient fire flow, low pressure, or future growth, are typically required to justify pipe replacement; and
- Evaluation of total head loss compared to the length of pipe.

5.5 Model Development

The model was developed in InfoWater 12.2 by Innovyze. This program analyzes steady state flows and pressures in pressurized systems. The pipe network in the model is based on a numbering system for each pipe segment and junctions (nodes). Pipe information includes length, start node, end node, C-value, and diameter. Junction information includes elevation, demand, demand patterns, and coordinates. Other information on pumps, storage, and supply sources such as pump curves, reservoir/tower head range and overflow elevation, hydraulic valve settings, and fixed-head supply sources (i.e. WTPs) are also incorporated into the model.

Model scenarios for the existing year and future planning periods are evaluated for the following demand conditions to determine the distribution system's capabilities, need, and location for additional supply, piping, storage, and pumping:

- Maximum day;
- Peak hour;
- Minimum hour plus storage replenishment; and
- Maximum day plus the fire flow requirement.

The maximum day scenario tests whether the water supply has sufficient capacity and if the demands can be met throughout the system while maintaining adequate pressures. The peak hour scenario tests the adequacy of the storage facilities and distribution system to supply high rates of flow. The minimum hour scenario simulates the ability of the water distribution system to replenish tank storage overnight. The maximum day plus fire flow scenarios represent the performance of the water distribution system with a fire flow demand at a specific location on the maximum day.

5.6 Diurnal Evaluation

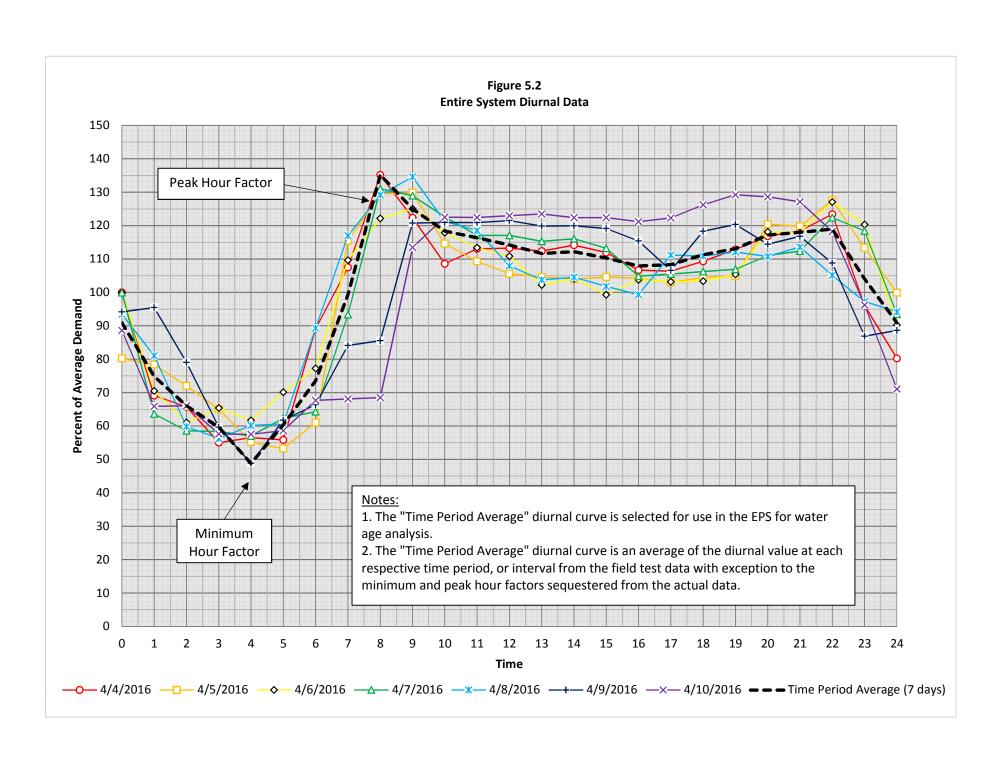
Diurnal curves represent changes in water demand over the course of a day, reflecting times when the City's customers are using more or less water than the average for that day. The average demand over the 24-hour period on the maximum day represents 100 percent on the diurnal curve. From the diurnal curve, equalization requirements and peak hour and minimum hour factors for each pressure zone are determined. Equalization requirements refer to the amount of storage needed for use during peaking times when system demand exceeds system supply.

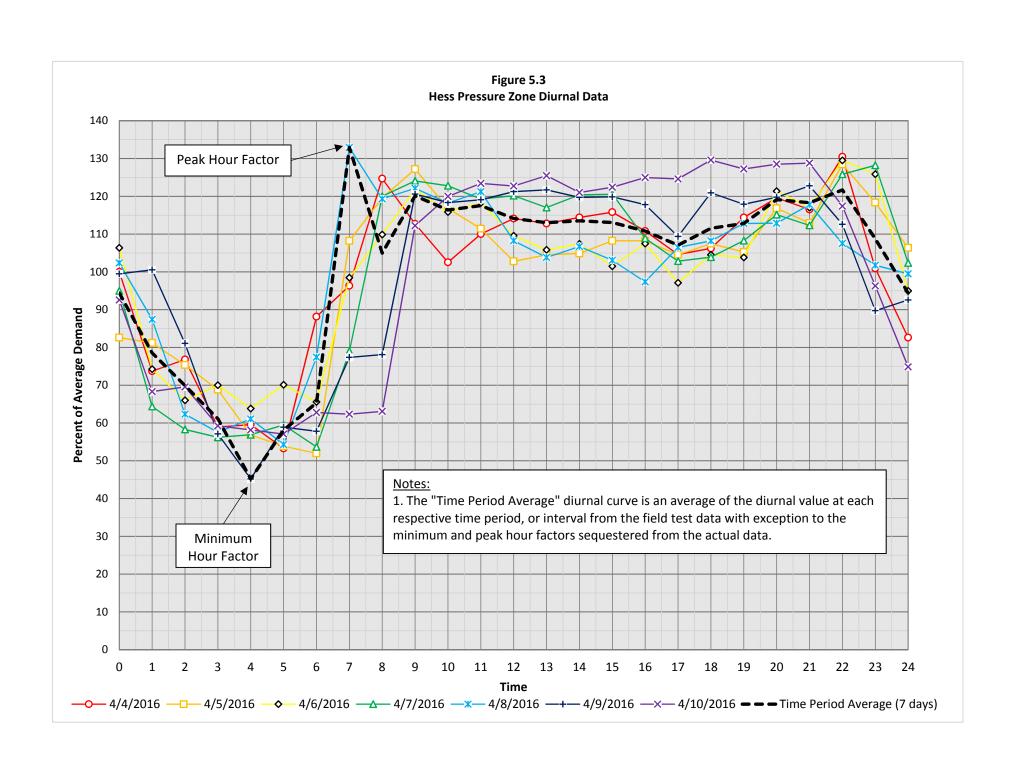
The diurnal curve for the entire system is illustrated in Figure 5.2 and the diurnal curves for Hess, Northeast, East, and West Maple pressure zones are illustrated in Figures 5.3, 5.4, 5.5, and 5.6 respectively; Appendix C includes the diurnal calculations for each curve. The entire system diurnal pattern is applied for extended period simulation modelling and pressure zone specific diurnal patterns are used to determine the equalization storage requirement of each pressure zone. A summary of the minimum hour and peak hour factors for each day during field testing is listed in Table 5.3 and a summary of the diurnal data from 2016 and the 2006 Water Master Plan is listed in Table 5.4 for comparison. Increases in equalization are consistent with other cities over this time period; as average water usage declines and peak hour factors remain at similar levels, the equalization storage factor increases.

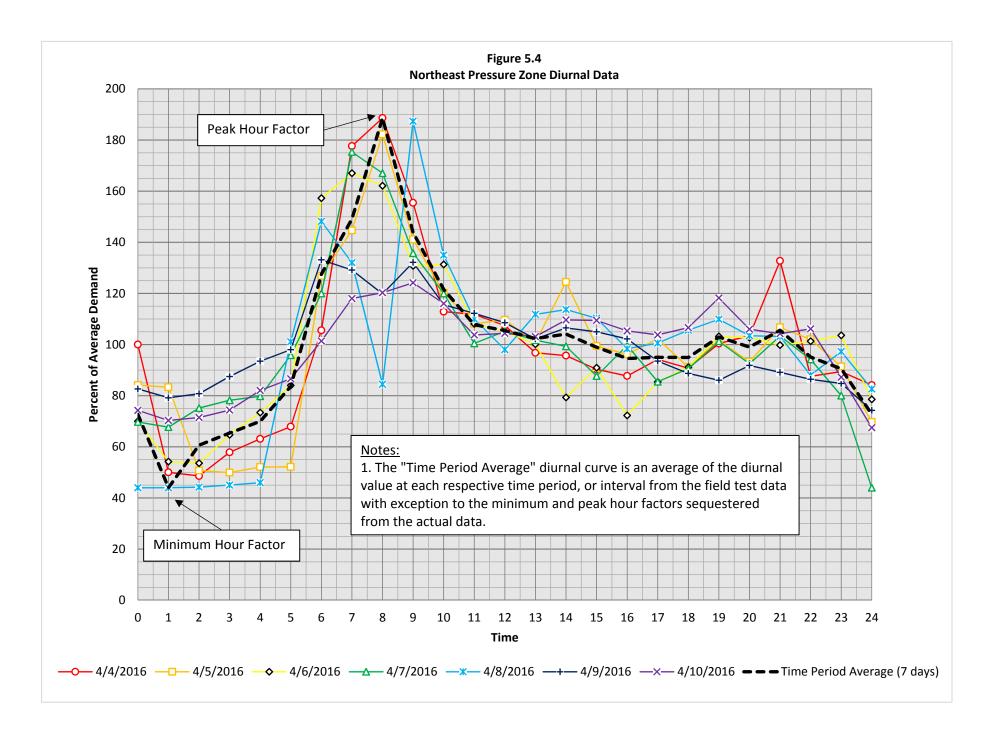
5.7 Fire Flow Requirement

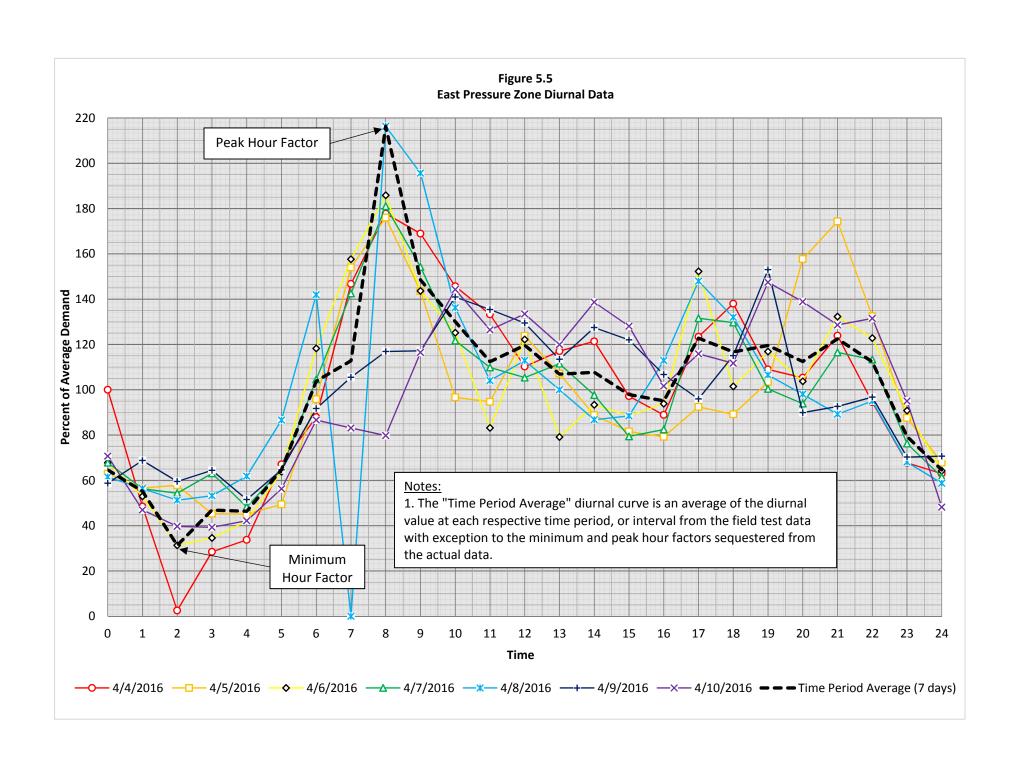
Fire protection storage includes water that must be available at all times to fight the most severe fires as determined by the Insurance Services Office (ISO), which provides recommendations for fire demand. Insurance companies use these studies to set insurance rates for city residents. The maximum ISO fire flow requirement is 3,500 gpm for 3 hours or 0.63 MG; this requirement could represent large industrial type customers or commercial buildings. Typically, residential fire flow requirements can be satisfied with 800 gpm to 1,200 gpm. A copy of the City's ISO report from 2012 is included in Appendix D.

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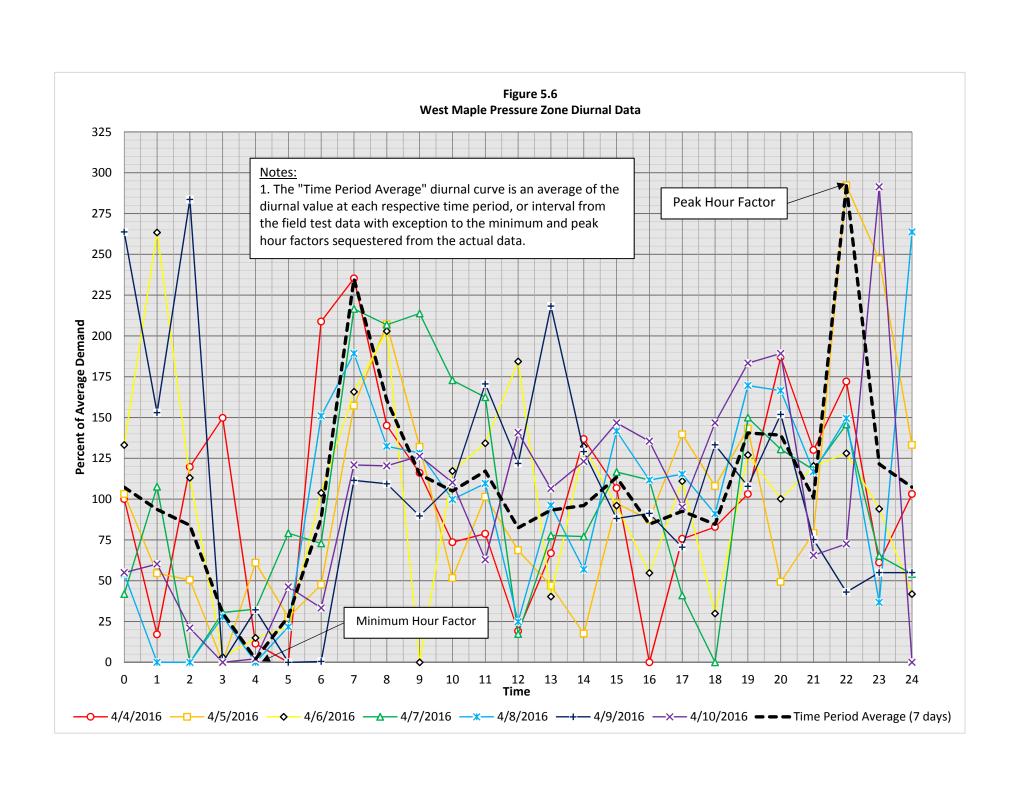


Table 5.3
Minimum Hour and Peak Hour Factors

Date	Syst	System		Hess		East		Northeast		West Maple	
Date	Minimum	Peak	Minimum	Peak	Minimum	Peak	Minimum	Peak	Minimum	Peak	
April 4, 2016	0.55	1.35	0.59	1.30	0.03	1.78	0.49	1.89	0.11	2.35	
April 5, 2016	0.53	1.30	0.52	1.28	0.45	1.76	0.50	1.82	0.18	2.92	
April 6, 2016	0.61	1.27	0.64	1.30	0.31	1.86	0.54	1.67	0.03	2.63	
April 7, 2016	0.57	1.31	0.54	1.28	0.48	1.81	0.68	1.75	0.17	2.17	
April 8, 2016	0.56	1.35	0.54	1.33	na	2.16	0.44	1.87	0.22	1.89	
April 9, 2016	0.49	1.22	0.45	1.23	0.52	1.53	0.79	1.33	0.32	2.84	
April 10, 2016	0.58	1.29	0.57	1.30	0.39	1.47	0.70	1.24	0.02	2.91	

Table 5.4

Diurnal Comparison - 2016 and 2003 Field Testing

Pressure Zone	Equaliza	ition (%)	Minimum I	Hour Factor	Peak Hour Factor		
Pressure zone	2016	2003	2016	2003	2016	2003	
Hess	13.7	11.1	0.45	0.45	1.33	1.39	
East	17.5	19.2	0.28	0.47	2.16	1.86	
Northeast	12.3	17.3	0.44	0.44 0.51 1.89		2.16	
West Maple ¹	27.5	na	0.02	na	2.92	na	
System	13.4	10.7	0.49	0.48	1.35	1.45	

Notes:

- 1. West Maple pressure zone was developed after the 2003 water master plan.
- 2. 2016 diurnal data developed from April 4th 11th.
- 3. 2003 diurnal data developed from July 11th 18th.

City of Wichita, Kansas

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6.0 EXISTING DISTRIBUTION SYSTEM ANALYSIS

The existing water distribution system is evaluated with the calibrated model to determine the following:

- Capacity of existing pump stations;
- Characterize system pressure;
- Water main hydraulics;
- Distribution system's ability to deliver fire flow demands;
- Water age;
- Adequacy of system storage; and
- Hydraulics and water age in the Hess Reservoir system.

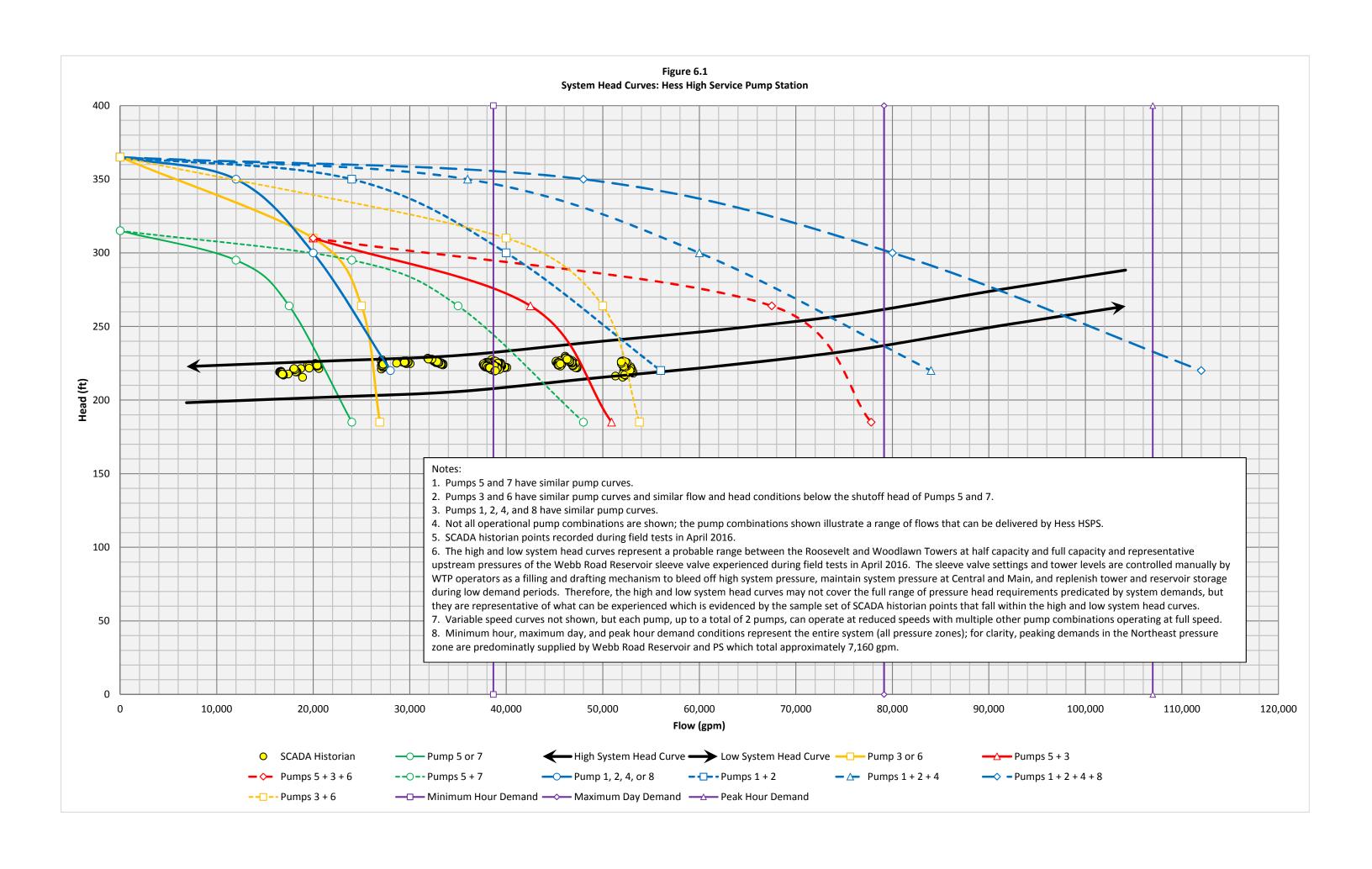
A separate model was developed to evaluate hydraulics in the Hess Reservoir system. Both models use a combination of static and extended period simulations (EPS) for evaluation and are intended to identify the strengths and weaknesses of the existing distribution system; therefore, this analysis does not include any improvements. The calibrated model is then used to identify and evaluate capital improvements for the future planning periods in years 2020, 2035, and 2045 as discussed in Section 11.0 – Distribution System Master Planning and Analysis.

6.1 Pumping

6.1.1 Hess High Service Pump Station

Hess HSPS is the City's primary pump station that provides water to the distribution system from a combination of eight pumps and has a firm capacity of approximately 215 MGD. System head curves for Hess HSPS are illustrated in Figure 6.1 and include individual pump curves and a sample of curves with typical multiple pump combinations. There are considerably more combinations available since each pump, up to two pumps, can be operated at reduced speed which provides operators a broad pump selection from which to choose. HSPS operating points from SCADA historian data are also included in Figure 6.1 to illustrate how measured pumping conditions relate to the system head curves generated by the hydraulic model. For the purpose of this analysis, system head curves are based on a constant suction head and do not include minor losses in the reservoir system or HSPS suction piping.

Pressure control is very important to the City's operation of Hess HSPS. Based on historical operations, water main breaks in the downtown area have occurred when pressure increases above 93 psi at Central and Main, therefore, the City has a target pressure of 92 psi. For clarity, water main breaks occur for a variety of reasons and/or combination of reasons due to age, material, deterioration caused by galvanic



action due to aggressive soils, inadequate restraint at joints, pressure transients caused immediate pump cycling or valve closures, loss of power at pump stations, submerged groundwater conditions, and/or inadequate bedding material/installation methods.

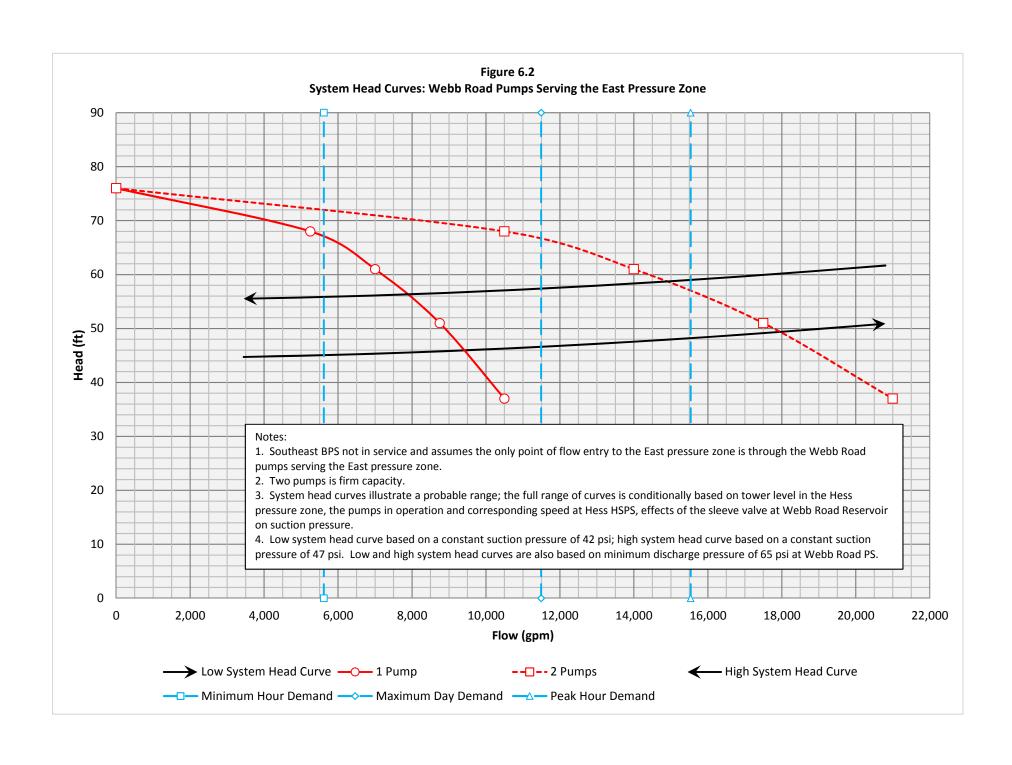
Under maximum day and peak hour demands, model results indicate the pressure at the HSPS and at Central and Main is approximately 99 psi and 92 psi. For comparison, review of the SCADA historian data during the field tests recorded average pressures of 97 psi and 92 psi at the HSPS and at Central and Main respectively under flows ranging from 50 MGD to 55 MGD. Hess HSPS has the operational flexibility to maintain the target pressure as system demands approach 114 MGD by a combination of the actions listed below. These actions are typically performed daily by WTP operators as the system is controlled manually:

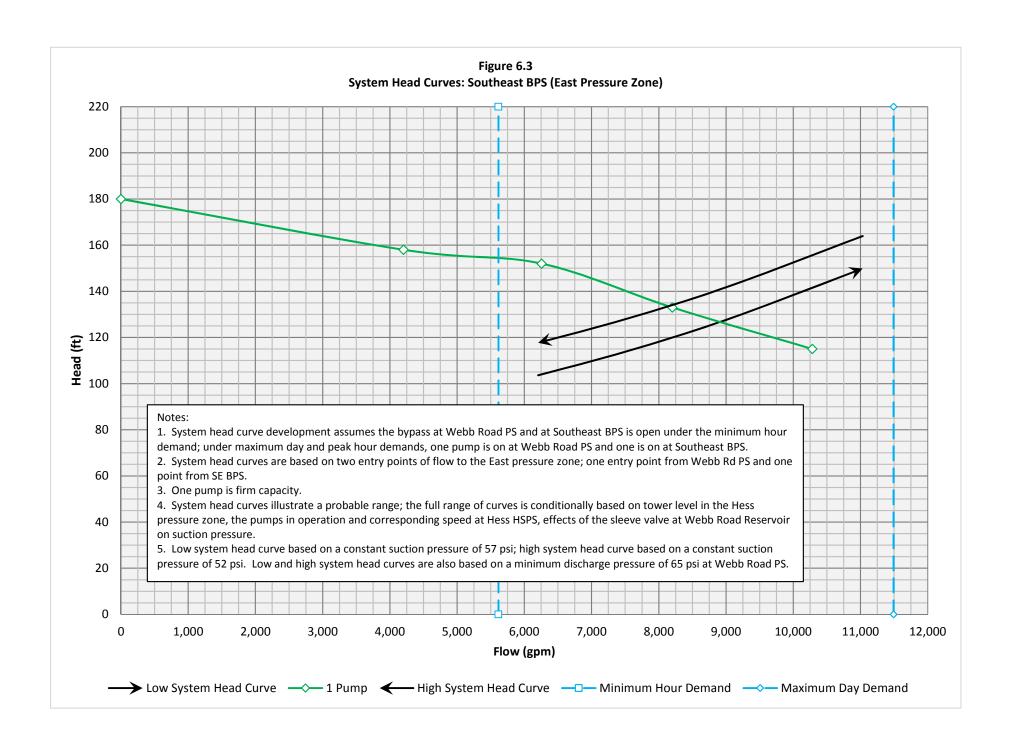
- Running a combination of higher head pumps (Nos. 1, 2, 3, 4, 6, or 8) at a constant reduced speed with the VFDs;
- Running a combination of higher head pumps at full speed and one higher head pump with a
 VFD to deliver varying rates of flow at an operator-selected constant discharge pressure;
- Lowering the operating level in the Roosevelt and Woodlawn towers to mitigate drafting and reduce the pressure or hydraulic gradient in the distribution system; and
- Adjusting the sleeve valve at Webb Road reservoir to sustain higher upstream pressure;
 - Sleeve valve adjustments that increase the upstream pressure result in lower flows into Webb Road reservoir.
 - Supplying the Northeast pressure zone entirely from Webb Road PS (37th St BPS off);
 this will increase turnover in the reservoir, but this in turn requires a longer time to
 replenish the volume exhausted by peaking demands in the Northeast pressure zone.

The pumping capacity at Hess HSPS can adequately supply the 2016 projected minimum hour, maximum day, and peak hour demands required by the system of 55.6 MGD, 114.1 MGD, and 154.0 MGD respectively.

6.1.2 East Pressure Zone

The East pressure zone is the second largest pressure zone, after Hess pressure zone, in the distribution system in terms of geographical size, total length of pipe, water demand, and is supplied by the Webb Road PS and the Southeast BPS. System head curves and corresponding pump curves for both pump stations are illustrated in Figures 6.2 and 6.3 respectively and are based on a minimum discharge pressure of 65 psi at the Webb Road PS discharge header. During field testing, system demands were low, ranging





between 5.9 MGD and 6.7 MGD, so the bypass lines in each pump station were open; therefore, no SCADA historian data is available for comparison with the system head curves. The pump combinations illustrated in each figure include up to firm capacity, which is defined as the pumping capacity with the largest pump out of service, and is listed below:

- Webb Road PS: two pumps delivering a combined total of approximately 25.0 MGD at 51 feet of pump head; and
- Southeast BPS: one pump delivering approximately 12.0 MGD at 130 feet of pump head.

Currently, Webb Road PS is the primary water supply mechanism serving the East pressure zone and is controlled by discharge pressure, targeting between 55 psi and 65 psi at the pump under varying rates of flow. WTP operators also monitor pressure at the intersection of Kellogg Drive and Webb Road which is at a higher elevation of approximately 1,367 feet (70th percentile with respect to the entire pressure zone) and has historically experienced lower pressure than the remainder of the East pressure zone; therefore, it is used as a secondary operational control point.

The pumping capacity at Webb Road PS is adequate to deliver the projected 2016 maximum day and peak hour demands of 16.5 MGD and 22.4 MGD respectively to the East pressure zone. The pumping capacity at Southeast BPS is adequate to deliver approximately half of the maximum day demand, 8.3 MGD, in parallel with one pump at Webb Road PS; however, this is not recommended because the pump pushes to the left and higher up on the pump curve resulting in a discharge pressure of approximately 120 psi and increases pressure by approximately 20 psi in the East pressure zone. Southeast BPS is adequate and better suited to deliver approximately half of the peak hour demand in parallel with one pump at Webb Road PS without exceeding tolerable pressure increases, approximately 10 psi, at Webb Road PS and at the intersection of Kellogg and Webb Road. Model results indicate a discharge pressure of approximately 107 psi at Southeast BPS under peak hour demand conditions.

City staff and WTP operators reported difficulties operating the Southeast BPS that are potentially caused by recycling water back into Hess pressure zone – when the BPS was in service there was minimal increase in discharge pressure. Modeling results validate this theory and is likely caused by an open pressure zone boundary valve or multiple valves that should normally be closed to isolate the Hess and East pressure zones. Southeast BPS was designed to pump into a closed pressure zone when demands are high and bypass flow during low and moderate demand periods. The bypass line and valves in the pump station should also be checked to confirm there is no reverse flow when the BPS is in service.

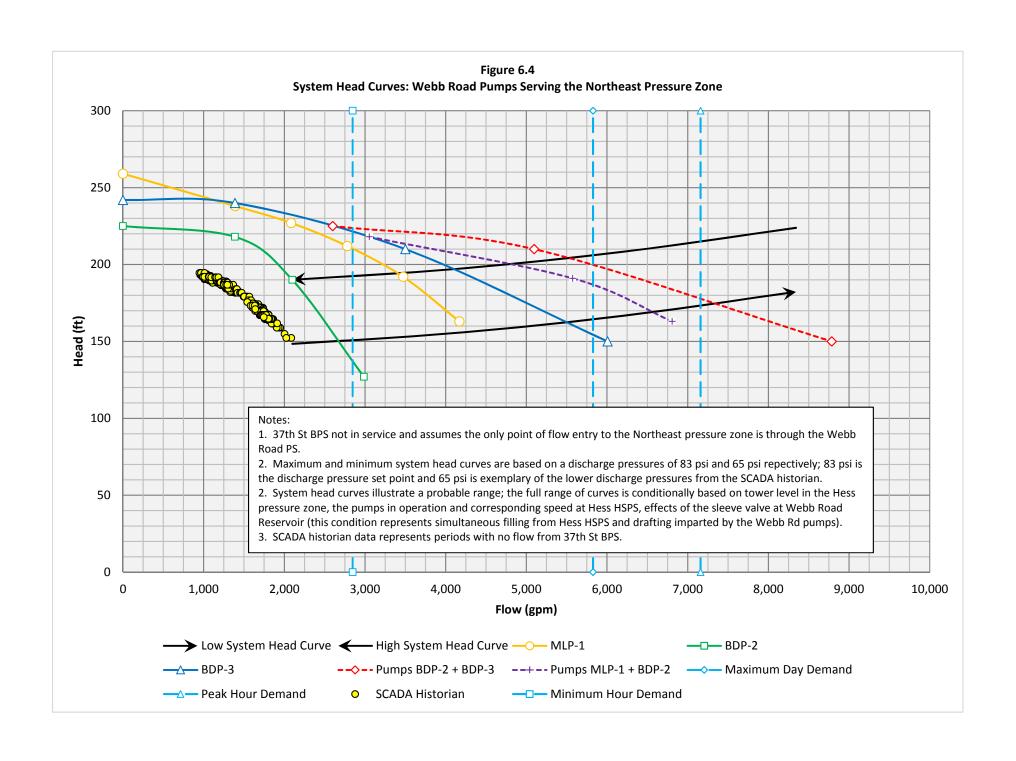
The Southeast BPS was installed to address low pressures south of Kellogg and Webb and in neighboring areas west of this intersection in the Hess pressure zone, meet the projected and expansive growth in the East pressure zone, and transfer of customers from the Hess pressure zone through a western expansion of the East pressure zone. Prior to 2006, pressures near the intersection of Kellogg and Webb were approaching 20 psi during peak demands. Southeast BPS includes a bypass and two 12-MGD pumps with open slots for two 24-MGD pumps. All pumps are constant speed as the Webb Road PS are equipped with VFDs. Future growth that was expected to occur beyond the northern and southern limits of the existing distribution system has been marginal and it was recommended to expand the East pressure zone into the Hess pressure zone about 3 miles west to Edgemoor Street, which would have also increased East pressure zone demand. While these conditions are working against the intended purpose, the model indicates the Southeast BPS pumps current use should be limited to higher peak hour demands in parallel with Webb Road PS.

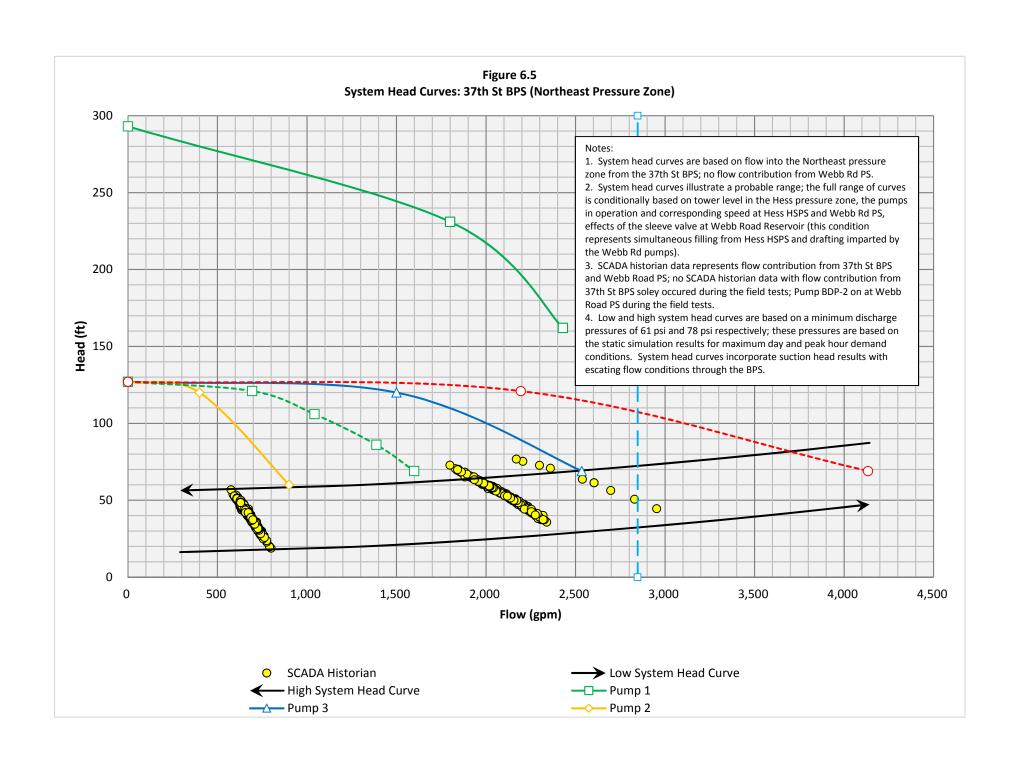
6.1.3 Northeast Pressure Zone

Webb Road PS is the primary water supply mechanism for the Northeast pressure zone and 37th Street BPS provides peaking assistance during high demand periods on an as-needed basis. System head curves for each pump station are illustrated in Figures 6.4 and 6.5 respectively. Each pump curve and curves for multiple pump combinations are also shown; other curves exist due to VFD capability of Pump BDP-3, but are not included for clarity.

Webb Road PS pump selection is based on maintaining a pressure of approximately 50 psi at the intersection of 34th and Webb Road. WTP operators indicated a target discharge pressure range between 50 psi and 60 psi at Webb Road PS; however, SCADA historian data indicates discharge pressures commonly occur between 65 psi and 85 psi. The SCADA historian data illustrated in the system head curve figures for Webb Road PS and 37th Street BPS also show a fairly definitive pattern below the published pump curves. The system head curves for each pump station developed by the model capture a representative sample of the SCADA historian points.

The pumping capacity at Webb Road PS can adequately supply the projected 2016 minimum hour, maximum day, and peak hour demands of 4.1 MGD, 8.4 MGD, and 10.3 MGD respectively assuming the published curves can be operationally replicated. No conclusions can be drawn on the pumping capacity of BDP-2 (Webb Road PS) because SCADA historian data suggests the pump curve has shifted; other possibilities could be a partially closed valve or an open pressure zone boundary isolation valve. Similarly, no conclusions can be drawn on the 37th Street BPS pumping capacity because SCADA





historian data suggests the pump curves have shifted or are being influenced by the mechanical governor on Pump No. 1. Pump testing should be conducted to develop current pump curves for each pump.

6.1.4 West Maple Pressure Zone

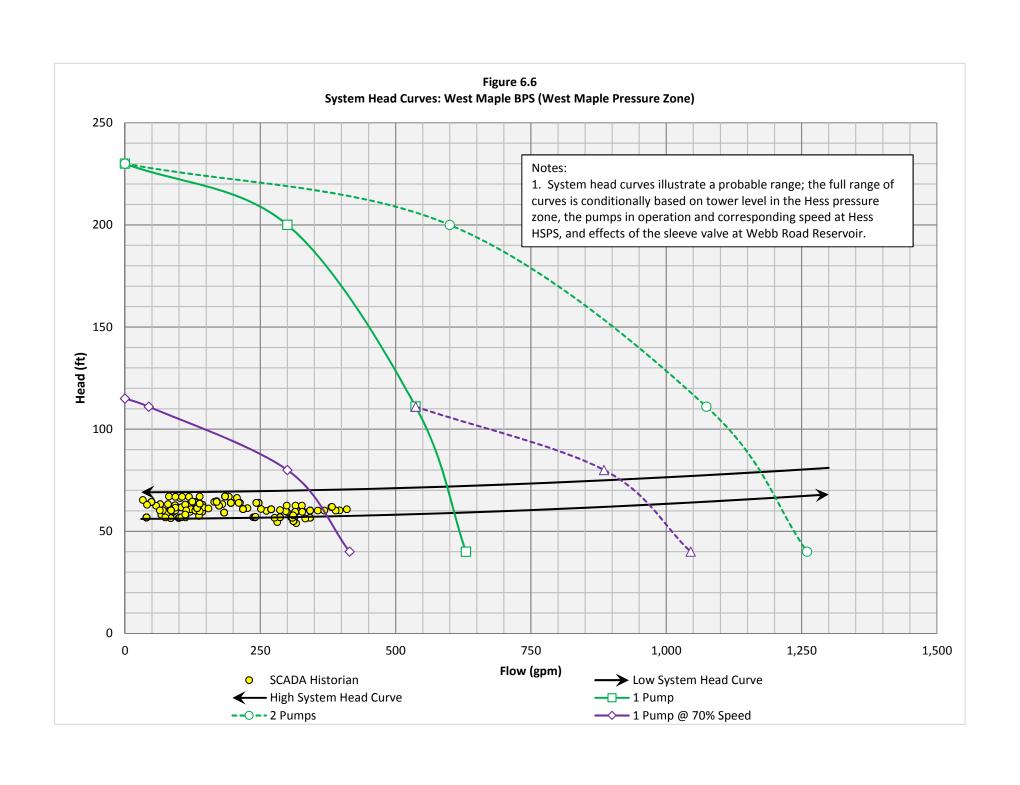
West Maple pressure zone is the smallest pressure zone in the distribution system in terms of geographical size, total length of pipe, demand and is supplied by the West Maple BPS. It is also a closed system and includes customers west of the Maple Street and City View Street intersection. This pump station is automated and the control mechanism is a constant discharge pressure of 80 psi for varying rates of flow. System head curves and multiple pump curve combinations for West Maple BPS are illustrated in Figure 6.6. There are considerably more combinations available since both pumps can operate in parallel and at reduced speeds. West Maple BPS operating points from SCADA historian data are also included in Figure 6.6 to illustrate how measured pumping conditions relate to the system head curves generated by the hydraulic model.

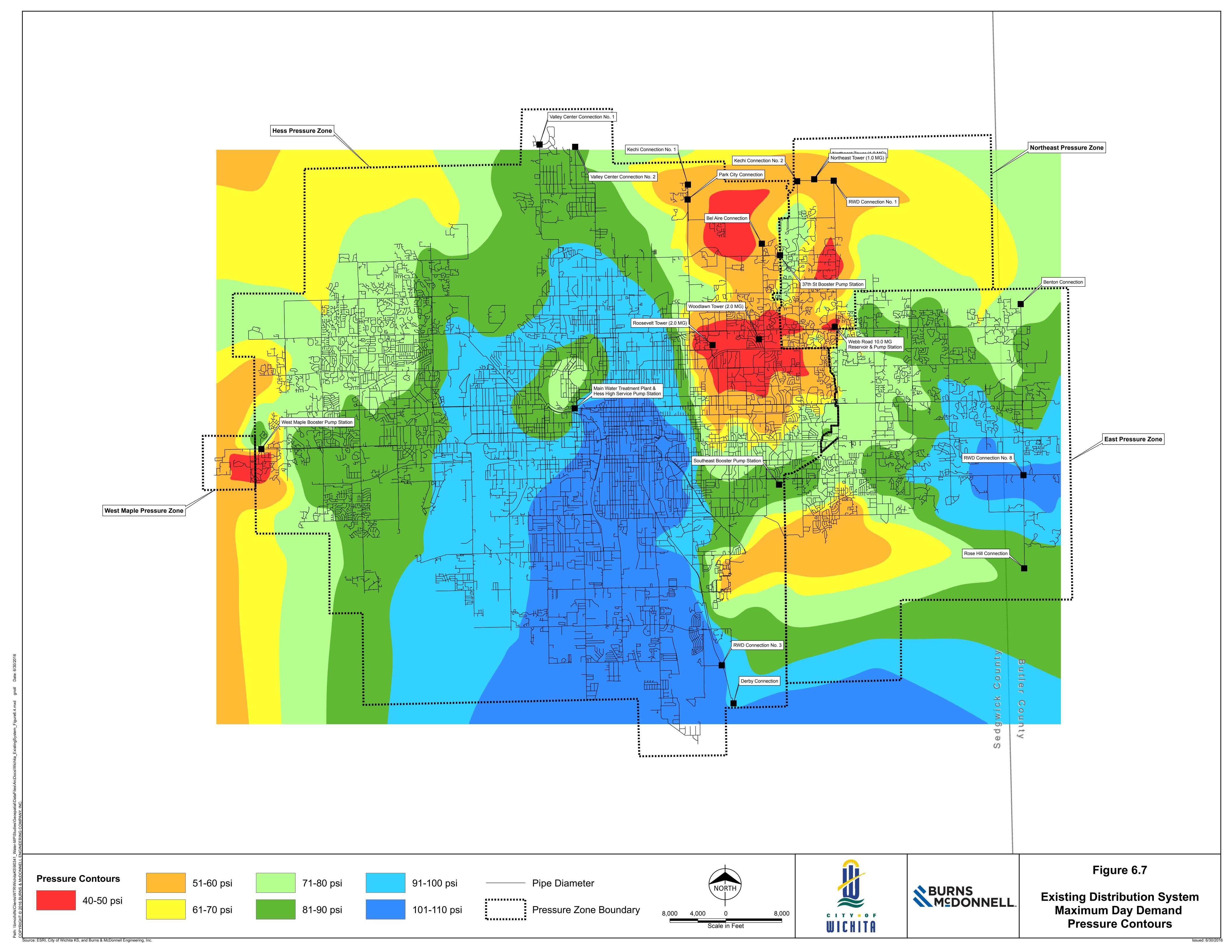
The pumping capacity of West Maple BPS can adequately supply minimum hour, maximum day, and peak hour demands of 50 gpm, 104 gpm, and 140 gpm respectively. Peaking demands can exceed 300 gpm, but for the purposes of this analysis evaluating a peak hour demand of 140 gpm is adequate because the pumping capacity far exceeds occasional high peaking demands in West Maple pressure zone.

City staff indicated a 1-inch diameter pipe was connected from the suction header to the discharge header to improve operation during low demand periods. Model results simulating this connection indicate the pump recycles water within the pump station effectively causing the pump to deliver more flow than is required by the pressure zone demand at a lower head. Since the pipe is small enough, the amount of water recycled through the pump station is marginal, and any decrease in discharge pressure affecting the pressure zone maybe unnoticeable. Therefore, this connection will be incorporated in the modeling evaluations for future planning periods and corresponding demand conditions of this pressure zone. Any impacts adversely affecting pump station operation or system pressure will also be addressed.

6.2 System Pressure

Model results for pressure under a maximum day demand of 114.1 MGD (entire system) are illustrated in Figure 6.7. System pressure is in compliance with the minimum recommended pressure of 40 psi in all pressure zones. Pressure declines from Hess HSPS toward the periphery of neighboring pressure zones primarily due to pipe friction losses before it is pumped and/or boosted into the Northeast, East, and West Maple pressure zones. However, there are areas in Hess and East pressure zones that experience higher





pressure due to lower elevations. Other metrics relating to pressure in each pressure zone under maximum day and peak hour demands are listed in Table 6.1.

The model results for distribution system pressure under maximum day and peak hour demands are adequate and do not reflect any areas of concern. Other minor points of interest regarding pressure are listed below:

- A small area east of Woodlawn Tower and southeast of the 21st St and Oliver St intersection in Hess pressure zone has pressures ranging between 36 psi and 40 psi under peak hour demands, but is still considered adequate.
- Pressures in the East pressure zone range between 32 psi and 82 psi and averages 59 psi with all
 flow pumped by Webb Road PS under peak hour demands. If one pump is on at Southeast BPS
 and Webb Road PS respectively, pressures range between 66 psi and 110 psi and averages 85 psi.

Under the minimum hour demand of approximately 55.7 MGD, Hess HSPS and the distribution system are capable of filling Woodlawn and Roosevelt towers. Model results indicate the storage in Webb Road Reservoir requires several hours during low demand periods of a 24-hour day to replenish peaking demands for the Northeast pressure zone unless additional pumps are cycled on at Hess HSPS to accelerate the process.

6.3 Water Main Hydraulics

Maximum day and peak hour demands of 114.1 MGD and 154.0 MGD respectively represent conditions that result in increased pipe velocities and higher headloss across the distribution system. Hydraulic criteria that apply to the evaluation of existing water mains are listed below:

- Transmission pipeline velocities are less than 5 feet per second (fps);
- Headloss less than 6 feet per 1,000 feet; and
- Evaluation of total headloss compared to the length of the pipe.

Under maximum day demands, over 99.9 percent of all water mains have velocities less than 5 fps. Only a small amount of water mains have velocities ranging between 5 fps and 8 fps and total approximately 1,260 linear feet (lf); this is minimal with respect to the approximately 1,800 miles of pipe in the system that are in compliance with the hydraulic criteria. These water mains have a marginal impact on the capacity and performance of the distribution system. Furthermore, the high velocity water mains are less

Table 6.1 Existing System Pressure

Elevation			Maximum Day Demand				Peak Hour Demand			
Pressure Zone	Range (ft)	Average (ft)	Demand (MGD)	Range (psi)	Average (psi)	HGL Range (ft)	Demand (MGD)	Range (psi)	Average (psi)	HGL Range (ft)
Hess	1,248 - 1,420	1,325	88.9	40 - 100	81	1,490 - 1,530	120.1	36 - 109	81	1,475 - 1,540
East	1,282 - 1,403	1,353	16.6	52 - 102	77	1,513 - 1,557	22.4	30 - 81	59	1,457 - 1,533
Northeast	1,370 - 1,432	1,399	8.4	49 - 78	63	1,536 - 1,560	11.3	51 - 83	64	1,534 - 1,573
West Maple	1,371 - 1,436	1,409	0.15	57 - 86	69	1,568	0.20	54 - 82	65	1,560
Total Demand	-	-	114.0				154.1			

Notes:

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^{1.} Additional pumps are on under peak hour demands because the distribution system is a closed system.

than 50 linear feet each and do not fall out of compliance with the headloss criteria. The total length of pipe with high velocity by diameter is listed below:

- 8-inch = 512 lf
- 12-inch = 34 lf
- 16-inch = 16 lf
- 20-inch = 57 lf
- 30-inch = 164 lf
- 42-inch = 70 lf
- 48-inch = 412 lf (discharge piping at Hess HSPS)

Peak hour demand conditions have similar water main hydraulic results as the maximum day demand condition. Over 99.9 percent of all water mains have velocities less than 5 fps. Only a small amount have velocities ranging between 5 fps and 10 fps and total approximately 2.5 linear miles of 6-inch through 48-inch diameter pipe; this is minimal with respect to the approximately 1,800 miles of pipe in the system that are in compliance with the hydraulic criteria. These water mains have a marginal impact on the capacity and performance of the distribution system. Furthermore, the high velocity water mains are less than 100 linear feet each and do not fall out of compliance with the headloss criteria. The total length of pipe with high velocity by diameter is listed below

- 6-inch = 384
- 8-inch = 1,790
- 12-inch = 3,343 lf
- 16-inch = 23 lf
- 20-inch = 164 lf
- 24-inch = 6.827
- 30-inch = 164 lf
- 42-inch = 70 lf
- 48-inch = 539 lf (discharge piping at Hess HSPS)

There are approximately 1.7 miles of 8-inch and 12-inch diameter pipes that exhibit headloss not in compliance with the hydraulic criteria, but typically have velocities less than 5 fps. With respect to water mains with higher headloss alone (velocity criterion excluded), unless they result in distribution system pressure less than 40 psi or fire flows less than 1,000 gpm, they do not need to be replaced or paralleled.

If a water main does not meet the hydraulic criteria under maximum day or peak demand conditions and result in inadequate pressure, then a hydraulic classification is assigned for these types of improvements and are evaluated in the future planning period model scenarios and sized for the future demand conditions. Based on the model results for water main hydraulics, the existing distribution system is robust and adequate to convey the 2016 demand conditions.

6.4 Available Fire Flow

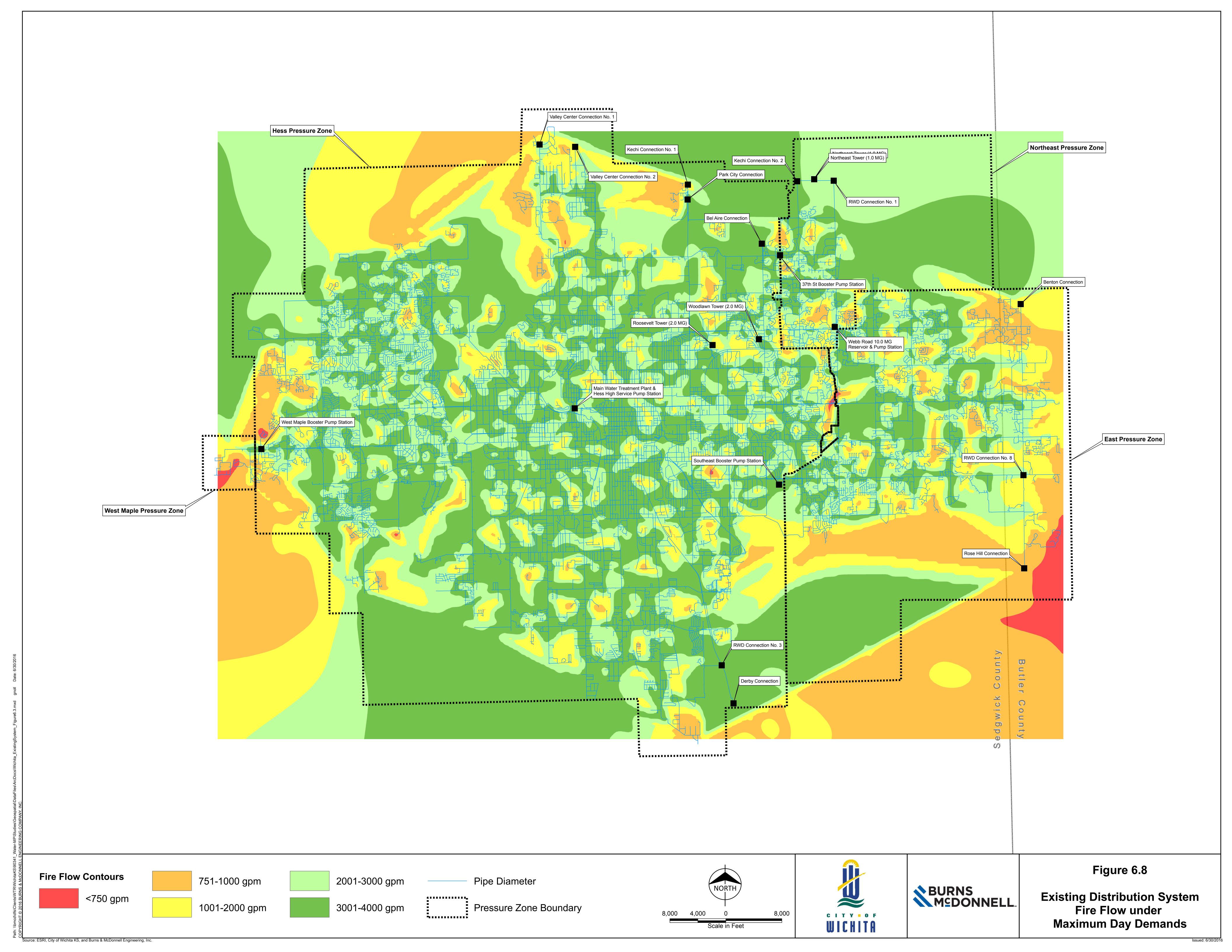
Fire flows across the distribution system are generally provided by Hess HSPS and assisted by other pump stations and tanks serving their respective pressure zones as follows:

- Fire flow for West Maple pressure zone is provided by Hess HSPS via the West Maple BPS bypass.
- Fire flow supply for the East pressure zone is provided by Hess HSPS via the Webb Road pumps that serve this pressure zone; Southeast BPS was not active in this scenario but is available to provide fire flow supply.
- Fire flow supply for the Northeast pressure zone is provided by Webb Road Reservoir and pump station pumps that serve this pressure zone; the 37th Street BPS was not active in this scenario but is available to provide fire flows which is supplied by Hess HSPS.

The model is used to evaluate the available fire flow at all junctions at a residual pressure of 20 psi under the maximum day demand of 114.1 MGD. There are approximately 19,350 junctions in the existing distribution system model and each junction is assigned a fire flow of 1,000 gpm. The adequacy of the distribution system to convey fire flows can be characterized by the amount of junctions resulting in available fire flow less than 1,000 gpm. Only 70 junctions, or 0.4 percent of all junctions, result in available fire flows less than 1,000 gpm and only about 20 junctions, or 0.1 percent of all junctions, result in flows less than 800 gpm. Typically, residential fire flow needs can be satisfied with 750 to 1,200 gpm.

Fire flow contours for the existing distribution system are illustrated in Figure 6.8 and show that the existing distribution system is robust and can provide adequate fire flow under maximum day demand conditions throughout the City. With exception to about three small areas with fire flows between 750 gpm and 1,000 gpm, the remaining lower fire flows that are less than 750 gpm consist of 4-inch and 6-inch dead end water mains that only permit flow in one direction. Areas with fire flows ranging between 750 gpm and 1,000 gpm are listed below:

• Dead end water mains in the West Maple pressure zone;



- The area northwest of the Central Ave and Webb Rd intersection in the Hess pressure zone; this is the eastern periphery of Hess pressure zone; and,
- Dead end water mains southeast of the Butler Rd and SW 120th St intersection in the East pressure zone; this is the eastern periphery of the East pressure zone.

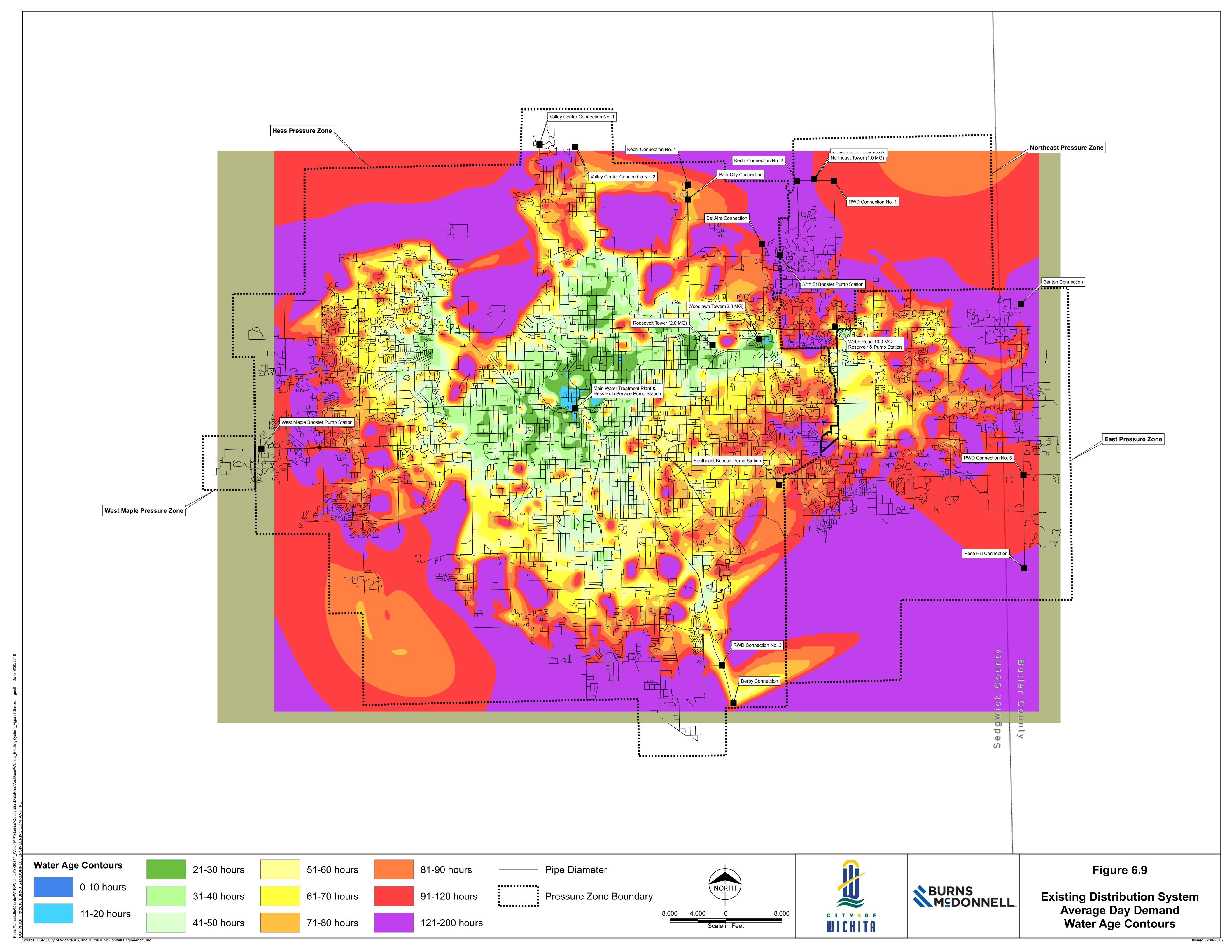
6.5 Water Age

The water quality analysis computes water age in the distribution system to evaluate residence time in tanks and assist in predicting areas in the distribution system with the greatest potential for water quality deterioration. EPS model scenarios evaluate water age under average day and maximum day demand conditions of 62.0 MGD and 114.1 MGD respectively. The EPS must include a time period extensive enough to capture the longest travel time within the distribution system to reach equilibrium. The average day demand EPS spans a 27-day period and the maximum day demand EPS spans a 21-day period. For clarity, evaluating the maximum day demand of the year for 21 days consecutively is only conducted to capture the longest travel time in the system and is not used as a design condition or for master planning. The average water age in the distribution system is a weighted average of the water age and corresponding demand for every junction in the model with respect to the total system demand.

Water age contours based on an average day demand of 62.0 MGD are shown in Figure 6.9. Distribution system areas resulting in the highest water age under average day demand conditions include the periphery Hess pressure zone, most of the Northeast pressure zone, and the eastern and southern periphery of the East pressure zone. The average water age over the entire distribution system under average day demand conditions is approximately 2.9 days (69 hours). The average water age under average day demand conditions for each pressure zone is listed below:

- Hess Pressure zone = 2.5 days (61 hours);
- East pressure zone = 3.7 days (88 hours);
- Northeast pressure zone = 4.8 days (114 hours); and
- West Maple pressure zone = 7.4 days (177 hours).

Contours with higher water age shown in Figure 6.9 represent dead end mains with little demand and/or peripheral areas with long runs of 12-inch and 16-inch mile-grid transmission lines where water demand begins to decline. These dead end mains may represent supply lines for future customers or areas with no current customers present; if customer consumption/demand increases similar to the surrounding area, then the water age would decrease in proportion to the increase in demand. Water age contours are based



on junctions with demand greater than 0 gpm; junctions with no demand on dead end water mains have infinite water age.

The average age over the entire distribution system based on maximum day demand conditions is approximately 2.7 days (64 hours). The distribution system locations resulting in the highest water age under maximum day demand conditions include a smaller area of the vicinities described above for the average day demand.

6.6 Storage Evaluation

The amount of storage required is dependent on multiple factors related to diurnal usage, fire flow needs, and the amount of emergency storage desired by the City. Typically, there are three types of storage provided in water distribution systems:

- Equalization storage is the storage required to make-up the difference between the amount of
 water demanded by customer consumption and the rate at which the water is supplied to the
 system by the WTP or diurnal usage patterns.
- Fire storage is the amount of storage required for fire flow conditions and is governed by the types of customer facilities in the distribution system. The fire flow demand is typically set by the Insurance Services Office (ISO). The 2007 ISO report for the City established a fire flow of 3,500 gpm; the required duration needed to receive full credit for this component of the ISO scoring system is 3 hours. Specific buildings (customer facilities) are also identified in the ISO report that require a fire flow demand of 7,000 gpm. Higher fire flow requirements can be indicative of large commercial or industrial type facilities. Fire flow requirements greater than 3,500 gpm for 3 hours can be the responsibility of the customer.
- Emergency storage is a quantity designated by the City and represents the amount of storage desired in excess of the equalization and fire storage. For the purposes of this evaluation, emergency storage is the effective storage remaining after the equalization and fire storage requirements are fulfilled. Emergency storage also represents a storage surplus.
- A storage deficit occurs when the minimum storage requirement, which includes equalization and fire storage, is less than the effective storage in the system and/or pressure zone.

System storage can be provided in multiple ways, at multiple locations, with either dedicated or shared service, and not all system storage can be defined as effective storage. Total storage represents the physical volume of a tank or reservoir and effective storage represents the usable volume of a tank or reservoir. For example, the total storage in the Hess reservoir system is approximately 35.1 MG, but the

current effective storage is much less because the bottom portion (below a water level of 4.0 ft) cannot be pumped due to an inoperable vacuum priming system (note, this assumes the pumps are on when the water level is above 7.0 ft). Effective storage can be elevated or pumped storage as described below:

- Elevated storage is effective if the bottom elevation of the tank bowl can provide adequate pressure under fire flow conditions.
- Typically ground storage is only termed effective if the firm capacity of the PS exceeds the maximum day demand of the area served by the pump station in systems with elevated storage (also known as open systems) and backup power is available.
 - o If there is no elevated storage (also known as closed systems), then the pumping capacity must be at least equal to the peak instantaneous demand (in lieu of the maximum day demand) plus the fire flow demand, and have a backup power supply, for ground storage to be termed effective. The City does not have peak instantaneous flow records; therefore, the peak hour demand plus the fire flow requirement is applied for determining the effective pumping capacity.
- Total storage and firm pumping capacities for each pressure zone, as previously discussed in Section 4.0, is summarized in Table 6.2.

The total storage in Hess reservoir system for each pressure zone is allocated based on the 2015 maximum day demand of the pressure zones it serves and is listed in Table 6.3. For clarity, the storage volumes listed in Table 6.3 represents total storage, not necessarily effective storage. The Hess reservoir system provides storage for the Hess, East, and West Maple pressure zones directly; it also provides storage for the Northeast pressure zone directly via the 37th Street BPS and indirectly via Webb Reservoir. The relationship of these facilities within the distribution system are illustrated in Figure 6.10.

This storage evaluation is based on maximum day demands experienced in 2015 and intended to quantify current deficits and/or surplus storage volumes that can be allocated for emergency service. For clarity, system storage for future planning periods and respective demand projections in 2020, 2035, and 2045 are evaluated in Section 11.0 and include capital improvements to address any deficits that are identified.

6.6.1 Northeast Pressure Zone Storage Evaluation

Total storage for the Northeast pressure zone totals 13.6 MG and includes a portion from the Hess reservoir system (2.57 MG), Webb Road Reservoir (10.0 MG), and the Northeast Tower (1.0 MG); however, not all of the total storage is considered effective.

Table 6.2
Summary of Storage and Pumping by Pressure Zone

Storage				Firm Capacity by Pressure Zone								Backup Power		
Pressure				Hess	Northeast		East			West Maple	Backup Power			
Zone	Volume	e ¹ (MG)	Total	Hess HSPS	Webb Road PS	37th Street BPS	Total	Webb Road PS	Southeast BPS	Total	West Maple	Status	Capacity	Location
	Ground	Elevated	(MG)	(MGD)	(MGD)	(MGD)	(MGD)	(MGD)	(MGD)	(MGD)	(MGD)	Status	(MGD)	Location
Hess	35.1	4.0	39.1	215.0								yes	97.2	Hess HSPS ²
Northeast	10.0	1.0	11.0		8.0	2.4	10.4					yes	8.0	Webb Road PS ³
East							-	25.0	12.0	37.0		yes	25.0	Webb Road PS ⁴
West Maple							-				0.8	no		Note 5

Notes:

- 1. Volume listed represents available storage based on the physical demensions; the effective storage, for example, at Hess is less than the available storage because Hess HSPS cannot currently pump below a water level of 4.0 feet due to an inoperable vacuum priming system (assuming the pumps are on when the water level is above 7.0 ft).
- 2. The pumping capacity with backup power of 97.2 MGD assumes 3 pumps in operation at 264 ft of pump head as estimated by City staff.
- 3. A backup power project, currently under construction (April 2017), will increase the pumping capacity with backup power to 16.2 MGD.
- 4. A backup power project, currently under construction (April 2017), will increase the pumping capacity with backup power to 37.0 MGD.
- 5. The fire flow requirement and emergency storage is provided by Hess Reservoir system and HSPS.

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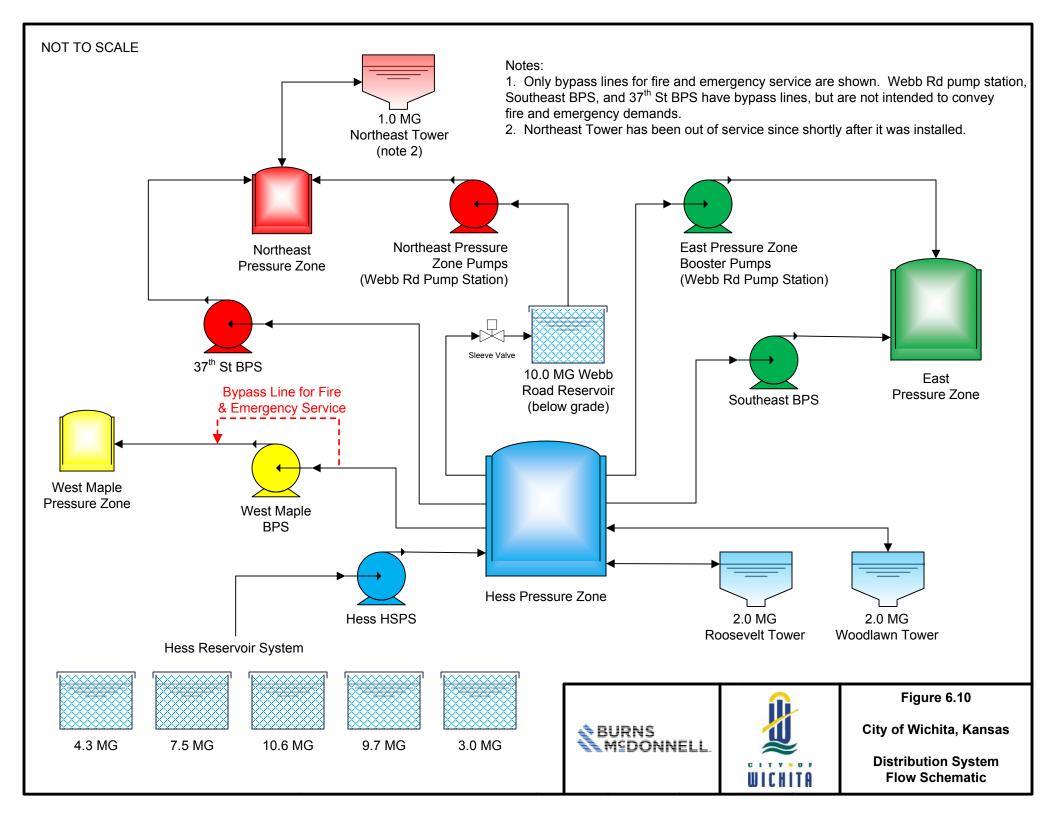
Table 6.3
Available Storage Allocation to Pressure Zones

			Pressure Zone Storage Allocation ^{1,2} (MG)					
Storage	Туре	Storage Volume (MG)	2015 Maximum Day Demand (MGD)					
Storage	туре		60.8	11.3	0.1	5.7		
			Hess	East	West Maple	Northeast		
Roosevelt Tower	elevated	2.0	2.0					
Woodlawn Tower	elevated	2.0	2.0					
Northeast Tower	elevated	1.0				1.0		
Hess Reservoir	ground	10.6	8.3	1.5	0.014	0.8		
Hess Reservoir	ground	9.7	7.6	1.4	0.013	0.7		
Hess Reservoir	ground	7.5	5.8	1.1	0.010	0.6		
Hess Reservoir	ground	4.3	3.4	0.6	0.006	0.3		
Hess Reservoir	ground	3.0	2.3	0.4	0.004	0.2		
Webb Reservoir ³	ground	10.0				10.0		
Total Available S	torage (MG)	50.1	31.4	5.1	0.05	13.6		

Notes:

- 1. The shared storage allocation in the Hess Reservoir system for each pressure zone is based on it's portion of the total 2015 maximum day demand of 78.0 MGD.
- 2. The storage allocation listed is termed available storage; it is not necessarily termed effective storage.
- 3. Webb Reservoir only provides pumped storage for the Northeast pressure zone; it does not supply any other pressure zones.

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Effective storage for the Northeast pressure zone totals 9.07 MG and includes the Hess Reservoir storage allocation (2.57 MG) plus the effective storage in Webb Reservoir. City staff indicated a minimum water level of 7.0 ft is required to start a pump; therefore, effective storage in Webb Reservoir is considered the volume above 7.0 ft and is equivalent to 6.5 MG. The Northeast Tower is not considered effective storage, as it has been removed from service.

The minimum storage requirement for the Northeast pressure zone is 1.31 MG and includes fire and equalization storage. Storage for fire is 0.63 MG and is based on the maximum ISO fire flow requirement of 3,500 gpm for a period of 3 hours. Equalization storage is 0.68 MG and is based on the 2015 maximum day demand of 5.7 MGD and an equalization factor of 12 percent as indicated in the diurnal analysis discussed in Section 5.0.

Emergency storage for the Northeast pressure zone totals 7.76 MG and is considered the remainder of effective storage after the minimum storage requirement is fulfilled. The Hess Reservoir system and Webb Reservoir provide 2.57 MG and 6.5 MG of effective storage respectively. This surplus (7.76 MG) can be allocated for emergency service or any portion thereof designated by the City. If the full surplus is allocated for emergency storage, then the City has approximately 1.35 days, or 32.4 hours, of emergency storage based on the 2015 maximum day demand of 5.7 MGD.

Another scenario to review considers a designated emergency storage amount desired by the City. For example, if the City elected not to rely on the effective storage from the Hess Reservoir system allocation and designated half a day (12 hours) of emergency storage at Webb Reservoir, then the active head range is equivalent to 8.32 ft and includes fire, equalization, and emergency storage for 12 hours based on a maximum day demand of 5.7 MGD; therefore, the City could operate Webb Reservoir between 7.0 ft and 15.32 ft.

The methodology for determining the total storage allocation, minimum storage requirement, effective storage, emergency storage, and the example designating an emergency storage duration for the Northeast pressure zone is included in Calculation 6.1 of Appendix E and is summarized in Table 6.4 below:

Table 6.4 - Northeast Pressure Zone Storage Evaluation Summary

Assumes Uninterrupted WTP Production Supplying Hess Reservoir System, HSPS, & Webb Reservoir

Component	Quantity	Comments
2015 Maximum Day Demand (MGD)	5.7	Northeast pressure zone
Total Storage (MG)	13.6	Webb Rd Reservoir (10.0 MG), Northeast Tower (1.0 MG), & Hess Reservoir allocation (2.57 MG)
Effective Storage (MG)	9.07	Hess Reservoir allocation (2.57) + Webb Reservoir (6.5 MG)
Minimum Storage Requirement (MG)	1.3	Fire (0.63 MG) + Equalization (0.68 MG)
Emergency Storage (MG) (Storage Surplus)	7.76	Surplus (effective storage – minimum storage requirement)
Equivalent Emergency Storage Duration (days)	1.35	Based on maximum day demand

Example for Designating Emergency Storage Duration

Component	Quantity	Comments
Designated Emergency Storage Duration ¹ (days)	0.5	Variable, at City's discretion
Equivalent Emergency Storage (MG)	2.85	0.5 days x 5.7 MGD
Minimum Storage Requirement (MG)	4.16	Fire + Equalization + Designated Emergency Storage
Equivalent Head Range for Minimum Storage Requirement (ft)	8.32	Minimum Storage Requirement x Webb Reservoir Volume/ft: (4.16 MG) x (20.0 ft / 10.0 MG)

Notes:

1. Duration indicated is used as an example only.

A storage evaluation for the Northeast pressure zone for the 2020, 2035, and 2045 planning periods is discussed in Section 11.0. Future planning periods assume the Northeast Tower is placed back in service conditionally based on operational changes for Webb Road PS to restore effectiveness. The new pumps replacing BDP-2 and BDP-3, currently under design by others, will also be included in the effective pumping capacity evaluation for the future planning periods.

6.6.2 East Pressure Zone Storage Evaluation

The methodology for determining total storage, effective storage, and the minimum storage requirement for the East pressure zone is the same as discussed above for the Northeast pressure zone; therefore, a summary of the results is listed below in Table 6.5 and a detailed review can be found in Calculation 6.2 of Appendix E.

Component Quantity Comments 2015 Maximum Day Demand (MGD) 11.3 East pressure zone Total Storage (MG) 5.1 Hess Reservoir system allocation Effective Storage (MG) 5.1 in Hess reservoir system Minimum Storage Requirement (MG) 2.66 Fire (0.63 MG) + Equalization (2.03 MG) Emergency Storage (MG) (Storage Surplus) 2.44 Surplus (effective storage – minimum storage requirement)

Based on maximum day demand

Table 6.5 – East Pressure Zone Storage Evaluation Summary

Assumes Uninterrupted WTP Production Supplying Hess Reservoir System and HSPS

A storage evaluation of the East pressure zone for the 2020, 2035, and 2045 planning periods is discussed in Section 11.0.

0.21

6.6.3 West Maple Pressure Zone

Equivalent Emergency Storage Duration (days)

Storage for fire flow and any allowable emergency storage is provided by Hess Reservoir system and pumped directly from Hess HSPS to West Maple pressure zone via bypass piping at West Maple BPS. Therefore, the storage evaluation for the West Maple pressure zone is included in the storage evaluation for the Hess pressure zone. Subsequent storage evaluations of the West Maple pressure zone for the 2020, 2035, and 2045 planning periods are conditional based on the amount of growth and corresponding demand projections affecting this area of the distribution system.

6.6.4 Hess Pressure Zone Storage Evaluation

Hess pressure zone includes heavy industrial and large commercial type facilities that require higher fire flow demands. The fire flow requirement for these types of customers can be as high as 7,000 gpm for 4 hours which totals 1.68 MG. This exceeds the ISO maximum requirement of 3,500 gpm for 3 hours, but is more reasonable for the types of customers and facilities in this pressure zone and is applied to the fire storage component of the storage evaluation for the Hess pressure zone. The methodology for determining total storage, effective storage, and the minimum storage requirement for the Hess pressure zone is as previously discussed; therefore, a summary of the results is listed below in Table 6.6 and a detailed review can be found in Calculation 6.3 of Appendix E.

Table 6.6 – Hess Pressure Zone Storage Evaluation Summary

Assumes Uninterrupted WTP Production Supplying Hess Reservoir System and HSPS

Component	Quantity	Comments
2015 Maximum Day Demand (MGD)	60.9	Hess (60.8 MGD) + West Maple (0.06 MGD) pressure zones
Total Storage (MG)	31.4	Hess Reservoir system allocation (27.4 MG), Woodlawn (2.0 MG) and Roosevelt (2.0 MG) towers
Effective Storage (MG)	25.74	Considered the volume above a level of 4 ft in the Hess reservoir system and assumes pumps are on above a water level of 7 ft
Minimum Storage Requirement (MG)	10.2	Fire (1.7 MG) + Equalization (8.5 MG)
Emergency Storage (MG) (Storage Surplus)	15.54	Surplus (effective storage – minimum storage requirement)
Equivalent Emergency Storage Duration (days)	0.25	Based on maximum day demand

Notes:

A storage evaluation of Hess pressure zone for the 2020, 2035, and 2045 planning periods is discussed in Section 11.0.

6.6.5 Storage Evaluation for Hess, East, and West Maple Pressure Zones

The methodology for determining total storage, effective storage, and the minimum storage requirement for the Hess, East, and West Maple pressure zones collectively is as previously discussed; therefore, a summary of the results are listed below in Table 6.7 and a detailed review can be found in Calculation 6.3 of Appendix E.

Table 6.7 – Hess, East, and West Maple Pressure Zones Storage Evaluation Summary
Assumes Loss of WTP Production & a Finite Volume in Hess Reservoir System

Component	Quantity	Comments
2015 Maximum Day Demand (MGD)	72.2	Hess (60.8 MGD), East (11.3 MGD), and West Maple (0.06
2020 Maximum Day Demana (MOD)	,	MGD) pressure zones
Total Storage (MG)	36.5	Hess Reservoir system allocation (32.5 MG), Woodlawn (2.0
Total Storage (MG)	30.3	MG) and Roosevelt (2.0 MG) towers
		Considered the volume above a level of 4 ft in the Hess
Effective Storage (MG)	25.74	reservoir system and assumes pumps are on above a water
		level of 7 ft
Minimum Storago Poquiroment (MC)	11.1	Fire (1.7 MG) + Equalization (9.4 MG for Hess, East & West
Minimum Storage Requirement (MG)	11.1	Maple pressure zones)
Emergency Storage (MG)	14.64	Surplus (effective storage – minimum storage requirement)
Equivalent Emergency Storage Duration (days)	0.20	Based on maximum day demand

^{1.} The ability to lower storage in the Hess Reservoir system cannot be assessed without considering the minimum storage requirements of the Hess, East, and West Maple pressure zones collectively.

- F 0						
Component	Quantity	Comments				
Designated Emergency Duration ¹ (days)	0.083	Equivalent to 2 hours; variable, at the City's discretion				
Equivalent Emergency Storage (MG)	6.02	0.083 days x 72.2 MGD				
Minimum Storage Requirement (MG)	17.12	Fire + Equalization + Designated Emergency Storage				
Equivalent Water Level for Minimum Storage	7.32	Minimum Storage Requirement x Hess Reservoir Volume/ft:				

Example for Designating Emergency Storage

Notes:

The example for designating 2 hours of emergency storage based on a maximum day demand of 72.2 MGD provides marginal ability to lower storage in the reservoir system between 4.0 ft to 11.32 ft; the tradeoff for lowering active storage is less emergency storage in this example. Restoring the vacuum priming system is recommended to optimize the amount of emergency storage in Hess Reservoir system if pumps need to be started below a water level of 7.0 ft. If the vacuum priming system is not restored, then the reservoir system should maintain as much storage as possible.

The City has approximately 0.2 days, or 4.8 hours, of emergency storage for the Hess, East, and West Maple pressure zones under current maximum day demands. An emergency condition could represent loss of treatment capability and a finite volume of treated water stored in Hess Reservoir system; however, evaluating emergency storage for loss of treatment is not a basis for recommendations to build more storage. This emergency condition is evaluated to raise questions for the City to address such as:

- What conditions could eliminate water treatment and could they be addressed and/or restored in 4.8 hours or less under a maximum day demand of 72.2 MGD?
- Can raw water be diverted directly to the Hess Reservoir system?
 - If possible, what is the maximum production capacity the well field can provide?
 Assuming groundwater with disinfection is the only viable water source for this condition.
 - o Are any improvements required for the existing chlorine system to support this?
 - If the existing chlorine system cannot provide disinfection (for any reason) under these conditions, can adequate hypochlorite be mobilized and on-site within 4.8 hours.
 - If temporary disinfection must be utilized under these conditions, then it must be amended in the City's emergency response plan and approved by KDHE.
 - Can/should these provisions be included in the East WTP Facility Improvements project?
- When will the City institute emergency water use restrictions?

^{1.} Storage indicated is used as an example only.

6.7 Hess Reservoir System Hydraulics

A hydraulic model was developed independent of the raw water and water distribution system models to evaluate the Hess Reservoir and yard piping system. An EPS is used to evaluate reservoir turnover and water age. This model simulates the chlorine contact basin as the supply source delivering water through the yard piping and reservoir system and ending at Hess HSPS and is illustrated in Figure 6.11. Hess HSPS is simulated as a junction with the 2015 average day demand of 49.7 MGD. The diurnal curve established for the entire system, as discussed in Section 5.0, is applied to the average day demand and includes peak hour and minimum hour factors of 1.35 and 0.49 respectively. Other modelling features and assumptions included in hydraulic analysis are listed below:

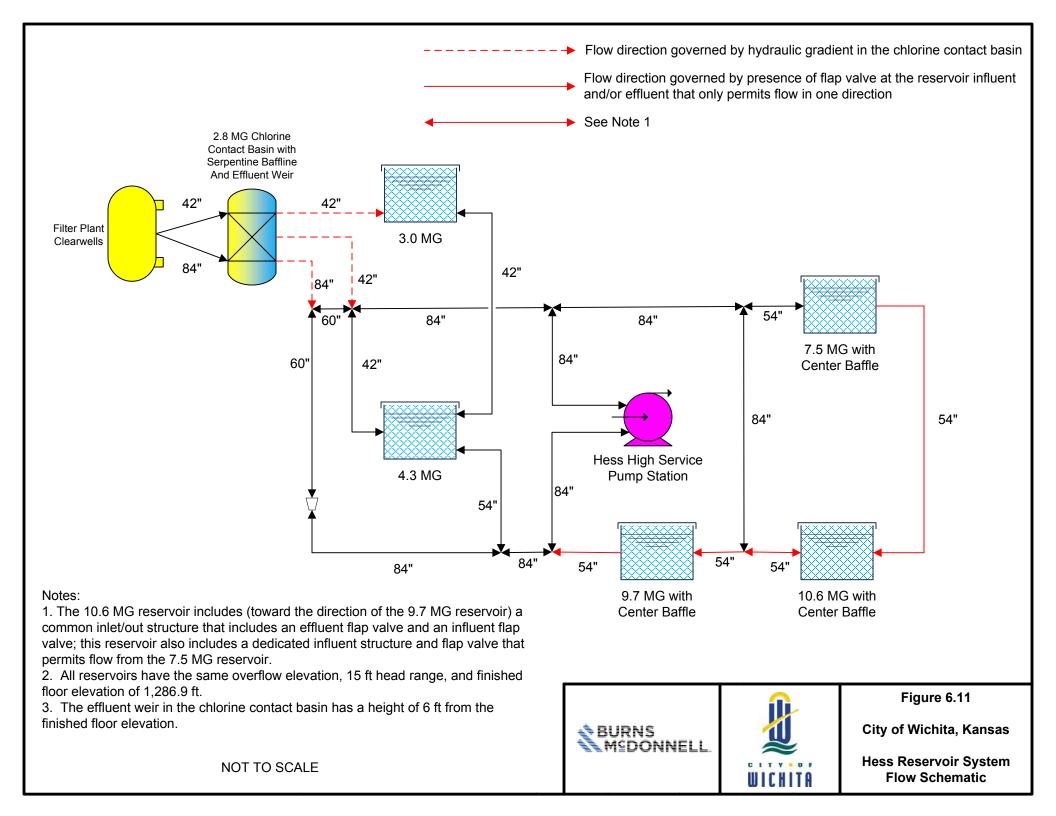
- Hazen Williams coefficient of 135 on all pipes;
- Minor losses for fittings, changes in pipe diameter, and reservoir entry/exit losses;
- Effective diameters are calculated based on the head range and volume for each reservoir;
- Constant water level in the chlorine contact basin of 1,297.0 ft (10.1 ft).
- Check valves are applied to pipes where the reservoir influent and/or effluent pipe has a flap gate valve; this includes the following:
 - o 7.5 MG reservoir (effluent only);
 - o 10.6 MG reservoir (influent and effluent);
 - o 9.7 MG reservoir (influent and effluent), and
- Check valves are applied to the 42-inch, 84-inch, and 42-inch pipes from the chlorine contact basin to prevent reverse flow; this simulates the effluent weir in the basin.

6.7.1 Reservoir Turnover

To maintain sufficient water quality in system storage, the recommended turnover volume can range from one fourth to one third of the active storage volume daily. The turnover criteria are only applicable if storage levels/volumes allocated for fire flow and equalization are not encroached. The low-end (one fourth tank volume) and high-end (one-third tank volume) turnover volumes based on the full or total volume of 35.1 MG of the reservoir system is listed below.

- Low End Turnover = 8.8 MG or a net reservoir water level change of approximately 3.8 feet in 24 hours.
- High End Turnover = 11.6 MG or a net reservoir water level change equivalent of approximately 5.0 feet in 24 hours.

The maximum fire flow requirement of 7,000 gpm for 4 hours (1.7 MG) and equalization storage requirement of 13 percent represents the minimum required storage volume in Hess Reservoir system.



The demand conditions and associated minimum storage requirement evaluated for reservoir turnover is listed below:

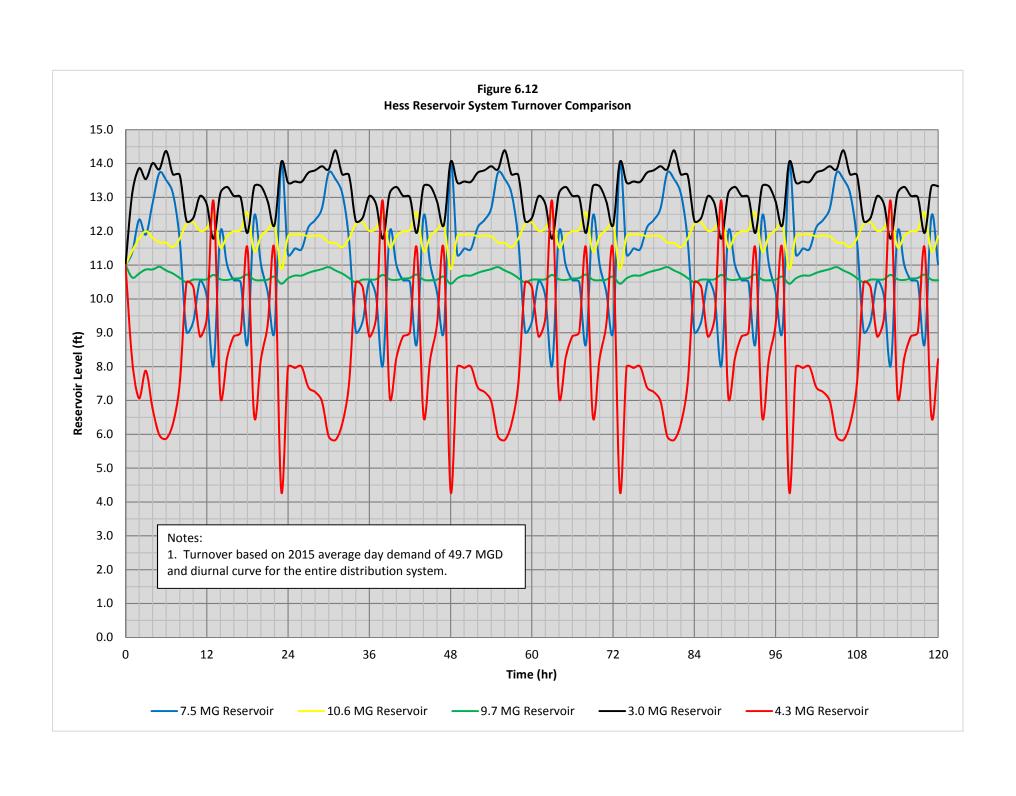
- 2015 average day demand of 49.7 MGD requires a minimum storage of 8.2 MG.
- 2016 average day demand of 62.0 MGD requires a minimum storage of 9.8 MG.
- 2016 maximum day demand of 114.1 MGD requires a minimum storage of 16.5 MG.

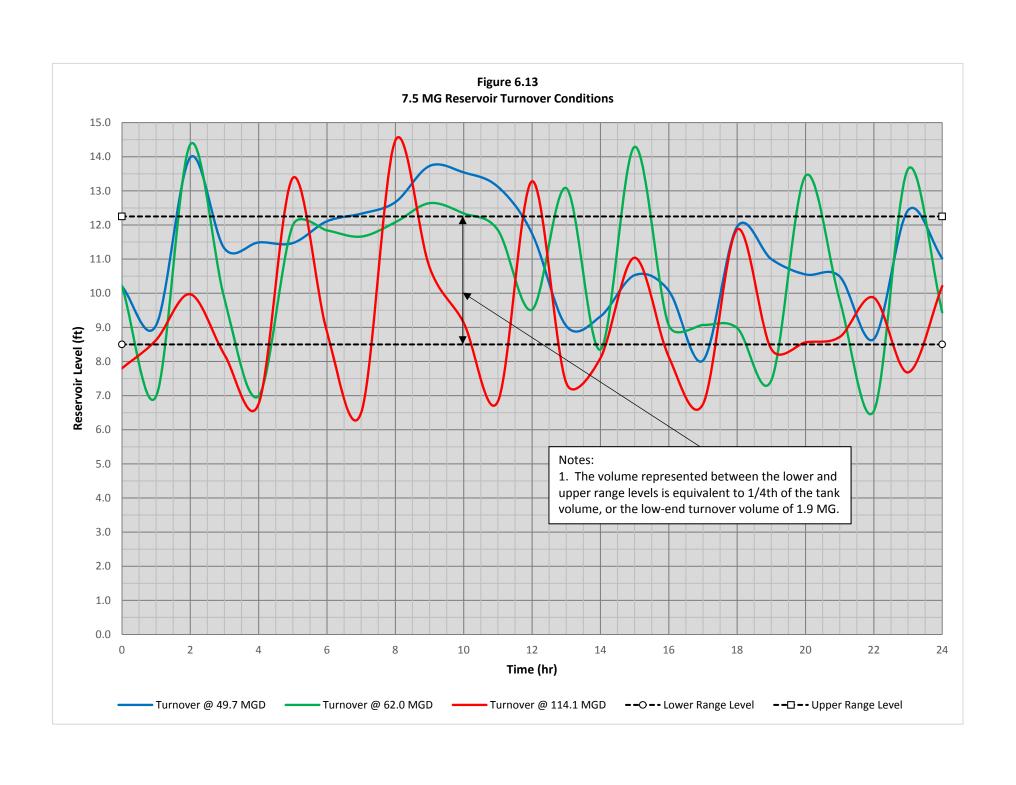
Turnover results for a 5-day EPS based on the 2015 average day demand is illustrated in Figure 6.12. While the reservoirs do float with each other, the variability in water level at any point in time is primarily due to the headloss experienced in the piping system and the forced path of flow through the 7.5 MG, 10.6 MG, and 9.7 MG reservoirs. Flap gates on the influent and effluent pipes of the 10.6 MG and 9.7 MG reservoirs and a flap gate on the effluent pipe of the 7.5 MG reservoir act similar to check valves and only permit water in one direction. Water takes the path of least resistance and in systems similar to this without hydraulic similitude from which Hess HSPS draws, the effect is varying water levels in each reservoir.

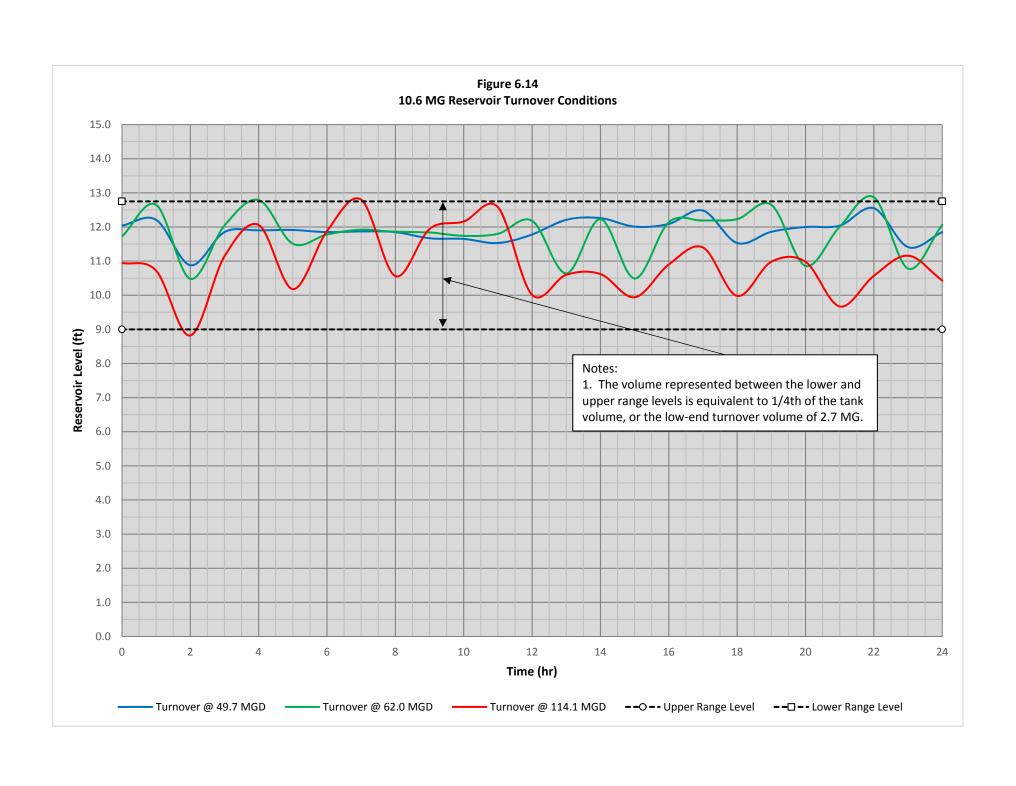
The degree of water level variability, from highest to lowest, is the 4.3 MG Reservoir followed by the 7.5 MG, 3.0 MG, 10.6 MG, and then the 9.7 MG reservoir. Figures 6.13, 6.14, 6.15, 6.16, and 6.17 illustrate the turnover capability in each reservoir under the demand conditions listed previously in this section. Since all reservoirs have a depth of 15.0 feet, the equivalent change in water level is 3.8 feet for the lowend turnover volume (note that the turnover volume is different for each reservoir). The 7.5 MG, 3.0 MG, 4.3 MG, and 10.6 MG reservoirs exhibit adequate turnover based on the 2015 and 2016 average day and maximum day demand conditions. The 9.7 MG reservoir does not meet the low-end turnover volume requirement of 2.4 MG or an equivalent change in water level of 3.8 feet in a 24-hour period. The turnover modelled for the 9.7 MG Reservoir is listed below:

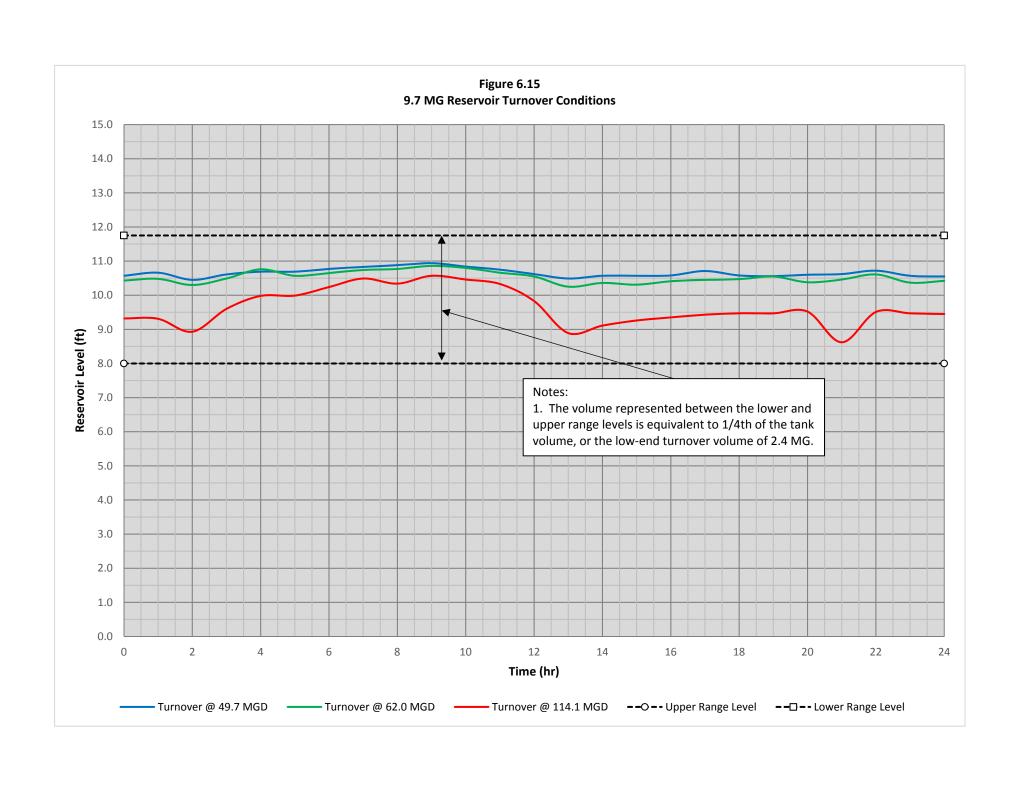
- 2015 average day demand:
 - o 0.6 MG or 1.0 feet of turnover;
- 2016 average day demand:
 - o 0.9 MG or 1.4 feet of turnover;
- 2016 maximum day demand:
 - o 2.1 MG or 3.2 feet of turnover.

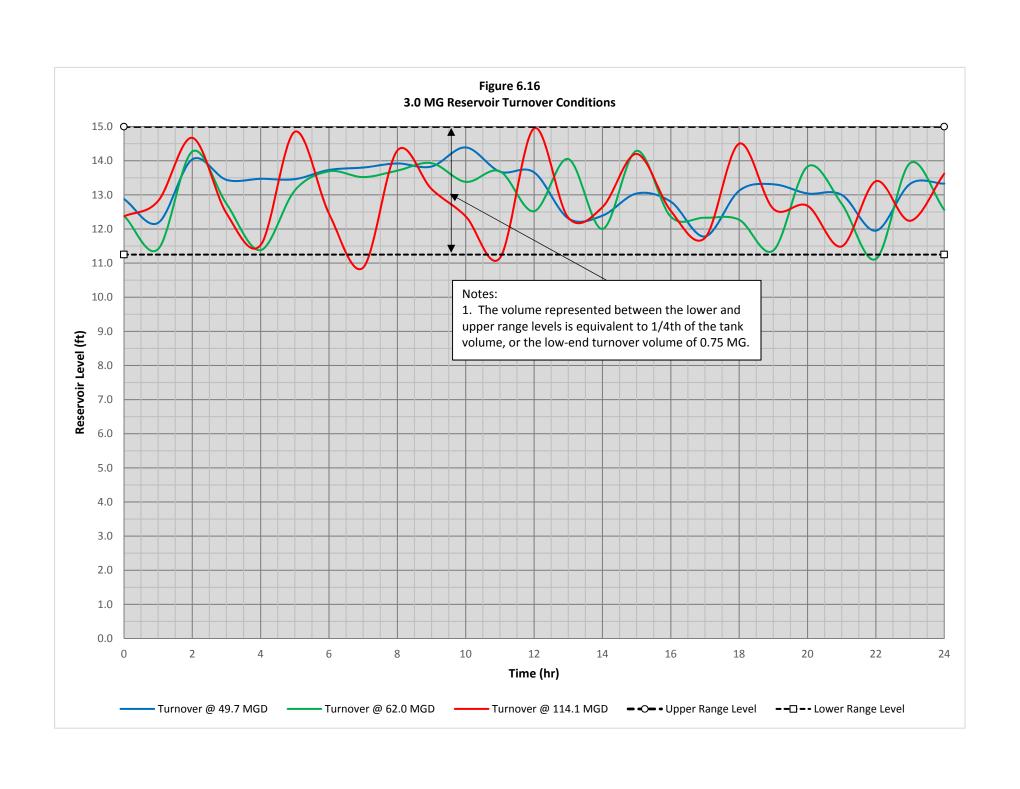
The minimum storage requirement is compared with the modelled turnover capability on a system-wide basis because the average water level over a 24-hour period is different in each reservoir. The average storage volume for each demand condition is listed below:

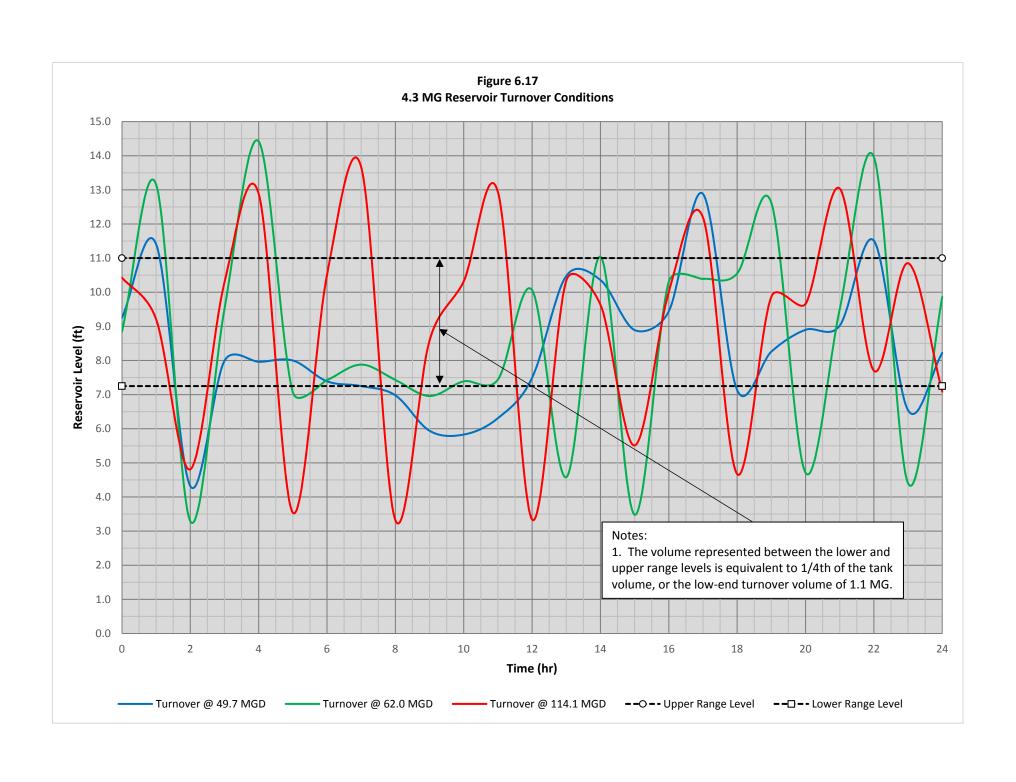












- 2015 average day demand of 49.7 MGD:
 - Average 24-hour storage volume is 25.9 MG which is greater than the minimum required storage volume of 8.2 MG;
- 2016 average day demand of 62.0 MGD:
 - Average 24-hour storage volume is 25.5 MG which is greater than the minimum required storage volume of 9.8 MG;
- 2016 maximum day demand of 114.1 MGD:
 - Average 24-hour storage volume is 23.7 MG which is greater than the minimum required storage volume of 16.5 MG.

6.7.2 Reservoir Water Age

A 5-day EPS is evaluated with the hydraulic model to determine water age in the reservoir system under the same demand conditions evaluated for turnover and are listed in Table 6.8. The water age in each reservoir reflects the turnover capability; low turnover is associated with higher water age and high turnover is associated with lower water age. With respect to the demand conditions evaluated for water age in the reservoir system, higher demands result in lower water age and lower demands result in higher water age.

Water Age (hr) Demand Conditions¹ Location 2015 Average Day 2016 Average Day 2016 Maximum Day 49.7 MGD 62.0 MGD 114.1 MGD 4 3 2 3.0 MG Reservoir 7 6 4.3 MG Reservoir 11 7.5 MG Reservoir 14 10 9 10.6 MG Reservoir 15 11 10 9.7 MG Reservoir 16 10 11 Hess HSPS 22 12 5

Table 6.8 – Existing Reservoir System Water Age

Notes:

1. Demand listed are referenced from the historical and projected water demands discussed in Section 3.0 of the report.

Model results suggest the highest reservoir water age can either occur in the 10.6 MG or the 9.7 MG reservoir; this variation is the result of the demand and corresponding water level in each reservoir which is influenced by the headloss in the piping system, the forced flow pattern through these reservoirs, and the diurnal curve.

6.7.3 Recommendations

The model results show adequate turnover and reasonable water age in the reservoir system. If water age at Hess HSPS and in the reservoir system were greater than 48 hours and if the chlorine residual entering the distribution system did not meet regulatory requirements, then additional evaluation should be shifted toward the disinfection application in the treatment process or reapplying disinfectant at the influent of Hess HSPS. To assess the impact of the reservoir and yard piping system on chlorine residual, grab samples at the influent and effluent of each reservoir should be collected to assess decay rate.

The reservoir model can be improved by calibration efforts to confirm water age and turnover results. Additional information needed for calibration is water level trending and flows in/out of each reservoir. Currently, the only data available collected by the SCADA system is the chlorine contact basin level, suction pressure at Hess HSPS, and flow out of Hess HSPS. Comparing water level and flow trends in each reservoir with EPS results is used to calibrate the model to simulate the headloss experienced in the yard piping system, which in return, provides a better approximation of likely flow contributions from each reservoir resulting in the water age at Hess HSPS.

The following tasks are recommended in the order they are listed:

- Grab sample testing at each reservoir and at multiple locations in each reservoir where possible.
 - Based on the measurements and decay rate evaluation, assess mixing system alternatives and viability of alternatives in reservoirs not meeting adequate results.
- Depending on the grab sample test results, prepare a field testing plan to collect water level trending in each reservoir during peak summer time and low winter time demand conditions to capture minimum and peak flow conditions from each reservoir.
 - Conduct calibration verification modeling to confirm water age and turnover results.
 - Water level trending data is required to determine the need for passive and/or active mixing system applications in eligible reservoirs, as part of the mixing capability is based on maximum and minimum filling/drafting rates.
- Determine if any influent piping modifications within the HSPS can be made to facilitate better turnover in the reservoirs with lower chlorine residuals, and if so, update the model for additional evaluation.

6.8 Summary and Conclusions

6.8.1 Pumping

6.8.1.1 Hess High Service Pump Station

Pressure control is very important to the City's operation of Hess HSPS as water main breaks in the downtown area have occurred when pressure increases above 93 psi at Central and Main, therefore, the City has a target pressure of 92 psi. Under maximum day and peak hour demands, model results indicate the pressure at the HSPS and at Central and Main is approximately 99 psi and 92 psi. Hess HSPS has the operational flexibility to maintain the target pressure as system demands approach 154 MGD (peak hour) by a combination of the actions listed below. These actions are typically performed daily by WTP operators as the system is controlled manually:

- Running a combination of higher head pumps (Nos. 1, 2, 3, 4, 6, or 8) at a constant reduced speed with the VFDs;
- Running a combination of higher head pumps at full speed and one higher head pump with a
 VFD to deliver varying rates of flow at an operator-selected constant discharge pressure;
- Lowering the operating level in the Roosevelt and Woodlawn towers to mitigate drafting and reduce the pressure or hydraulic gradient in the distribution system; and
- Adjusting the sleeve valve at Webb Road reservoir to sustain higher upstream pressure;
 - Sleeve valve adjustments that increase the upstream pressure result in lower flows into
 Webb Road reservoir.
 - Supplying the Northeast pressure zone entirely from Webb Road PS (37th St BPS off); this will increase turnover in the reservoir, but this in turn requires a longer time to replenish the volume exhausted by peaking demands in the Northeast pressure zone. Interstitial flows and/or demand conditions that cannot be delivered by Webb Road PS alone will require use of 37th BPS.

Other measures that should be considered for further evaluation in terms of pressure control include expanding the East pressure zone into Hess pressure zone; this would also increase the operating potential of Southeast BPS service in the East pressure zone.

The pumping capacity at Hess HSPS can adequately supply the 2016 projected minimum hour, maximum day, and peak hour demands required by the system of 55.6 MGD, 114.1 MGD, and 154.0 MGD respectively.

6.8.1.2 East Pressure Zone

The pumping capacity at Webb Road PS can adequately deliver maximum day and peak hour demands of 16.5 MGD and 22.4 MGD to the East pressure zone. The minimum hour demand of 8.0 MGD represents a condition where no booster pumping is required to the East pressure zone; there are other demand conditions that do not require booster service to the East pressure zone, but this decision should first consider pressure at Webb Road PS and at the intersection of Kellogg Drive and Webb Road (East pressure zone).

Southeast BPS can adequately deliver approximately half of the peak hour demand in parallel with one pump at Webb Road PS. Pressure increases above tolerable levels for continued service if Southeast BPS is in operation in parallel with one pump at Webb Road PS under the maximum day demand of 16.5 MGD. The absence of anticipated growth in the East pressure zone (from previous master planning efforts), lower system demands, and no East pressure zone expansion into the Hess pressure zone are all factors limiting the use of the Southeast BPS pumps; however, the model results indicate it can be used under the peak hour demand condition for which it was designed to cover.

The pressure zone boundary separating Hess and the East pressure zones should be confirmed; the model results suggest a valve or multiple valves could be opened (that should be normally closed) if there is no increase in discharge pressure at Southeast BPS when in service. Additionally, the bypass line in Southeast BPS should also be checked to confirm there is no reverse flow into Hess pressure zone and/or the suction header when both pump stations are in service. Additional discussion and evaluation of the control philosophy for the East pressure zone by Webb Road PS and Southeast BPS is discussed in Section 11.0 for the future planning period scenarios.

6.8.1.3 Northeast Pressure Zone

The pumping capacity at Webb Road PS can adequately supply the minimum hour, maximum day, and peak hour demands required by the system of 4.1 MGD, 8.4 MGD, and 10.3 MGD respectively assuming the published curves can be operationally replicated. No conclusions can be drawn on the pumping capacity of BDP-2 (Webb Road PS) because the SCADA historian data suggests the pump curve has shifted. Similarly, no conclusions can be drawn on the 37th Street BPS pumping capacity because the SCADA historian data suggests the pump curves have shifted or are being influenced by the mechanical governor on Pump No. 1. New pumps at Webb Road PS are currently being designed by others and will be evaluated in the future planning period model scenarios; however, if the new pumps are not installed within a year at Webb Road PS, then pump testing should be performed on each pump to develop new

curves and compared to the published curves. Whether new or existing pumps reside at Webb Road PS, all pumps at 37th Street BPS should be tested to develop new pump curves. If pump testing results in pump curves like the published pump curves, then investigative efforts should include the following:

- Calibration confirmation of pressure transducers (suction and discharge) and flow meters at each pump station;
- Confirm the pressure zone boundary isolation;
- Confirm all valves that should be opened in each pump station are fully open;
- Confirm full valve closure on bypass pipes when Webb Road and Southeast BPSs are in service –
 bypass pipe valve status is conditional based on what pumps are running; and
- Confirm full valve closure on bypass pipes, if present, at wholesale customer connections and confirm reverse flow is not permitted from wholesale customer systems.

6.8.1.4 West Maple Pressure Zone

The pumping capacity of West Maple BPS can adequately supply minimum hour, maximum day, and peak hour demand conditions of 50 gpm, 104 gpm, and 140 gpm respectively. Model results simulating the 1-inch pipe connection from the discharge header to the suction header indicate the pump recycles water within the pump station effectively causing the pump to deliver more flow than is required by the pressure zone demand at a lower head. Since the pipe is small enough, the amount of water recycled through the pump station is marginal, and any decrease in discharge pressure affecting the pressure zone maybe unnoticeable. If water demand in West Maple pressure zone increases and diurnal patterns become more stable, for example consistent minimum hour and peak hour factors greater than 0.5 and less than 2.0 respectively, then the effectiveness of this pipe should be evaluated to determine if it is necessary. Conversely, if water demands increase and diurnal patters continue to be widely variable, then the size of the connection should be evaluated to determine if a larger diameter enhances pump station operation.

6.8.2 System Pressure

System pressure is adequate and in compliance with related hydraulic criteria under maximum day and peak hour demand conditions. Under minimum hour demands, Hess HSPS pumping capacity and the Hess pressure zone distribution system capacity are capable of replenishing storage in the Woodlawn and Roosevelt towers. Storage replenishment in Webb Road reservoir can require several hours during low demand periods depending on the pumps in operation at Hess HSPS.

6.8.3 Water Main Hydraulics

Over 99.9 percent of all pipes evaluated in the model comply with velocity and headloss criteria. The remainder of pipes have a velocity either exceeding 5.0 fps or headloss greater than 6 ft per 1,000 ft, but not both, and has a marginal impact on the capacity and performance of the distribution system under maximum day and peak hour demand conditions. The model results for water main hydraulics indicate the existing distribution system is robust, acceptable headloss for the demand conditions evaluated, and has adequate capacity to convey minimum hour, maximum day, and peak hour demand conditions.

6.8.4 Available Fire Flow

The distribution system can adequately convey a fire flow demand of 1,000 gpm or more at a residual pressure of 20 psi. Areas with lower fire flows ranging between 750 gpm and 1,000 gpm are listed below and are evaluated in the future planning period model scenarios to determine if fire flow improvements are required:

- Dead end water mains in the West Maple pressure zone;
- The area northwest of the Central Ave and Webb Rd intersection in the Hess pressure zone; this is the eastern periphery of Hess pressure zone; and,
- Dead end water mains southeast of the Butler Rd and SW 120th St intersection in the East pressure zone; this is the eastern periphery of the East pressure zone.

6.8.5 Water Age

Areas resulting in the highest water age under average day demand conditions include the periphery Hess pressure zone, most of the Northeast pressure zone, and the eastern and southern periphery of the East pressure zone, which, by all accounts, is expected as the majority of the distribution system functions as a closed system and these areas are the furthest from the WTP. The average water age for the entire distribution system under average day demand conditions is approximately 2.9 days (69 hours) and is as follows for each pressure zone:

- Hess Pressure zone = 2.5 days (61 hours);
- East pressure zone = 3.7 days (88 hours);
- Northeast pressure zone = 4.8 days (114 hours); and
- West Maple pressure zone = 7.4 days (177 hours).

The average water age for the entire distribution system based on maximum day demand conditions is approximately 2.7 days (64 hours). The distribution system locations resulting in the highest water age

under maximum day demand conditions include a smaller area of the vicinities described above for the average day demand.

6.8.6 Storage

A summary of the storage evaluations, based on the current maximum day demand for each pressure zone, for the following operating conditions are as follows:

- Uninterrupted WTP production supplying the Hess reservoir system:
 - Northeast pressure zone has adequate effective storage to satisfy the minimum storage requirement (fire plus equalization). There is approximately 1.35 days (32.4 hours) of storage that can be allocated for emergency use or the City could reduce the active storage in Webb Road reservoir depending on the desired amount of emergency storage.
 - East pressure zone has adequate storage in the Hess reservoir system to satisfy the minimum storage requirement and approximately 0.21 days (5.2 hours) of emergency storage based on its respective storage allocation. Based on the pumping capacity with backup power, Webb Road PS could deliver a 24-hour demand of approximately 11.6 MGD that would include a peaking demand of 25.0 MGD. If the City desired an effective pumping capacity with backup power to exceed the maximum day or peak hour demand in addition to fire flow, then backup power for one pump at Southeast BPS is required.
 - O Hess and West Maple pressure zones have adequate effective storage in the Hess reservoir system to satisfy the minimum storage requirement and approximately 0.25 days (6.1 hours) of emergency storage. Hess HSPS has adequate effective pumping capacity with backup power to deliver peak hour plus fire flow requirements in Hess pressure zone.
- Loss of WTP production and a finite volume in the Hess reservoir system:
 - Collectively, the Hess, East, and West Maple pressure zones have adequate effective storage in the Hess reservoir system to satisfy the minimum storage requirement and approximately 0.2 days (4.8 hours) of emergency storage. Restoring the vacuum priming system is recommended to optimize the amount of emergency storage in Hess Reservoir system if pumps need to be started below a water level of 7.0 ft. There is marginal ability to lower the active storage volume in Hess Reservoir system with the amount of emergency storage available based on a minimum water pumping level of 4.0 ft.

The latter emergency condition that considers loss of WTP production is evaluated to raise questions for the City to address such as:

- What conditions could eliminate water treatment and could they be addressed and/or restored in 4.8 hours (0.2 days) or less?
- Can raw water be disinfected and diverted directly to the Hess Reservoir system?
- When will the City institute emergency water use restrictions?

6.8.7 Hess Reservoir System Hydraulics

Collectively, the model results show that the reservoir system exhibits adequate turnover based on the 2015 and 2016 average day and maximum day demand conditions. Individually, however, the 9.7 MG reservoir does not meet the low-end turnover volume requirement of 2.4 MG, which is an equivalent change in water level of 3.8 feet over a 24-hour period. Model results for water age at Hess HSPS is approximately 22 hours (at pump suction header) based on the 2015 average day demand of 49.7 MGD; the water age for each reservoir is listed below:

- 3.0 MG reservoir at 4 hours;
- 4.3 MG reservoir at 11 hours;
- 7.5 MG reservoir at 14 hours;
- 10.6 MG reservoir at 15 hours; and
- 9.7 MG reservoir at 16 hours.

The low turnover volume in the 9.7 MG reservoir simulated in the model supports the low disinfectant residuals the City has detected in the reservoir system. Lower turnover results in higher water age and lower disinfectant residual and higher turnover results in lower water age and higher disinfectant residual. In 2016, City staff collected the following residuals in each reservoir:

- 3.0 MG reservoir at 3.08 mg/L;
- 4.3 MG reservoir at 2.9 mg/L;
- 7.5 MG reservoir at 0.80 mg/L;
- 10.6 MG reservoir at 0.60 mg/L; and
- 9.7 MG reservoir at 0.32 mg/L.

Model results indicate the highest reservoir water age can occur in either the 10.6 MG Reservoir or the 9.7 MG Reservoir; this variation is the result of the demand and corresponding water level in each reservoir which is influenced by the headloss in the piping system, the forced flow pattern through these reservoirs, and the diurnal curve. Multiple scenarios were evaluated to determine the ability to improve

turnover and lower water age in the current reservoir and yard piping system. These scenarios included the following alternatives:

- Alternative No. 1: removing the flap valve, which functions as a check valve that permits flow in one direction, on the effluent pipe of the 9.7 MG Reservoir.
- Alternative No. 2: removing the flap valve on the influent and effluent pipe of the 9.7 MG reservoir.
- Alternative No. 3: removing the flap valve on the effluent pipe of the 9.7 MG reservoir.
- Alternative No. 4: installing flap valves, or check valves for modeling purposes, on both 42-inch pipes entering the 4.3 MG Reservoir (one entering from the east and one enter from the west side of the reservoir) forcing the flow path to exit the 54-inch pipe at the reservoir; this condition simulates dedicated influent pipes and a dedicated effluent pipe.
- Alternative No. 5: isolating the 84-inch influent pipe supplying the north header of Hess HSPS to force flow through the 7.5 MG, 10.6 MG, and 9.7 MG reservoirs placing them in series.
- Alternative No. 6: eliminating flow in and out of the 3.0 MG Reservoir.
- Other scenarios simulating series-type flow through the reservoir system.

Each alternative simulated above resulted in an overall higher water age in the reservoir system. Reservoir turnover varied amongst each alternative, where some would increase while others would decrease from the turnover experienced under current operations, but not effectively improving, or lowering, water age in the system. Model results for water age in Alternative No.'s 1, 2, and 3 are listed in Table 6.9.

Table 6.9 - Water Age Results for Alternative Reservoir System Operations

	Water Age (hr)						
Location	2015 Average Day Demand of 49.7 MGD ¹						
	Alternative No. 1	Alternative No. 2	Alternative No. 3				
3.0 MG Reservoir	4	4	3				
4.3 MG Reservoir	13	25	28				
7.5 MG Reservoir	17	56	55				
10.6 MG Reservoir	18	56	55				
9.7 MG Reservoir	18	55	57				
Hess HSPS	10	52	54				

Notes:

- 1. The 2015 average day demand is selected to evaluate water age for the operating alternatives because lower demands result in less reservoir turnover and higher water age.
- 2. A description of each alternative is listed below:
 - a. No. 1: removing the flap valve on the effluent pipe of the 9.7 MG Reservoir.

- b. No. 2: removing the flap valve on the influent and effluent pipe of the 9.7 MG reservoir.
- c. No. 3: removing the flap valve on the effluent pipe of the 9.7 MG reservoir.

Model results for the other alternatives are not provided because the same conclusions apply, but can be simulated with the model to view the results. Alternative No. 1 did lower the water age at Hess HSPS to approximately 10 hours, versus the approximately 22-hour water age simulated by current conditions, but its effect increases water age and lowers turnover in the 7.5 MG, 10.6 MG, and 9.7 MG reservoirs because most of the water feeding Hess HSPS is conveyed directly from a combination of the chlorine contact basin, 3.0 MG Reservoir, and the 4.3 MG Reservoir.

The reservoir model can be improved with calibration efforts to confirm water age, turnover results, and determine viability of passive and/or active mixing system applications. Additional information needed for calibration is water level trending and flows in/out of each reservoir. Currently, the only data available collected by the SCADA system is the chlorine contact basin level, suction pressure at Hess HSPS, and flow out of Hess HSPS. Using water levels and flow trends in each reservoir to calibrate the model will accurately simulate the headloss in the yard piping system, which in return, provides a better approximation of likely flow contributions from each reservoir under different demand conditions. This will help identify the system demand that fosters adequate turnover and inform City staff and WTP operators when to implement the first option (submersible pump recycle option) to improve disinfectant residuals discussed in the paragraph below the bulleted list. The following tasks are recommended in the order they are listed:

- Grab sample testing at each reservoir and at multiple locations in each reservoir where possible.
 - Based on the measurements and decay rate evaluation, assess mixing system alternatives and viability of alternatives in reservoirs not meeting adequate results.
- Depending on the grab sample test results, prepare a field testing plan to collect water level trending in each reservoir during peak summer time and low winter time demand conditions to capture minimum and peak flow conditions from each reservoir.
 - Conduct calibration verification modeling to confirm water age and turnover results.
 - Water level trending data is required to determine the applicability of passive and/or active mixing system applications in eligible reservoirs, as part of the mixing capability is based on maximum and minimum filling/drafting rates.

Options to decrease water age in the reservoir system while maintaining adequate turnover without infringing on minimum storage requirements for the distribution system are limited based on the existing

yard piping, land availability, and reservoir arrangement. One option includes installing submersible pumps in the 9.7 MG and 10.6 MG reservoirs, which have the lowest turnover and highest water age per the model results and lowest disinfectant residuals per City staff, and pumping it to the 3.0 MG reservoir to blend and recycle the water, thereby lowering the overall water age in the reservoir system and forcing much needed turnover in the 9.7 MG and 10.6 MG reservoirs.

Another option to decrease water should evaluate and/or determine if any influent piping modifications within the HSPS can be made to facilitate better turnover in the reservoirs with lower chlorine residuals, and if so, update the model for validation.

Another option to decrease water age in the reservoir system is consolidating all 35.1 MG of storage into a single well baffled reservoir and providing hydraulic similitude in the yard piping between the reservoir and the influent pipes of Hess HSPS is a potential option to lower water age in the system and increase turnover. Capital cost and constructability factors need to be assessed to determine the viability of this option and consider site restrictions and limitations, construction time, and the ability to maintain adequate storage during construction in the reservoir system for what may only be a slight improvement in water age and turnover above what is currently adequate; however, a single well baffled reservoir with bifurcation (multiple storage cells) would provide optimal operational flexibility and allow City staff to shut down a storage cell for cleanout or shut down a cell during periods of low demand when the storage is unnecessary.

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7.0 RAW WATER MODEL CALIBRATION AND ANALYSIS

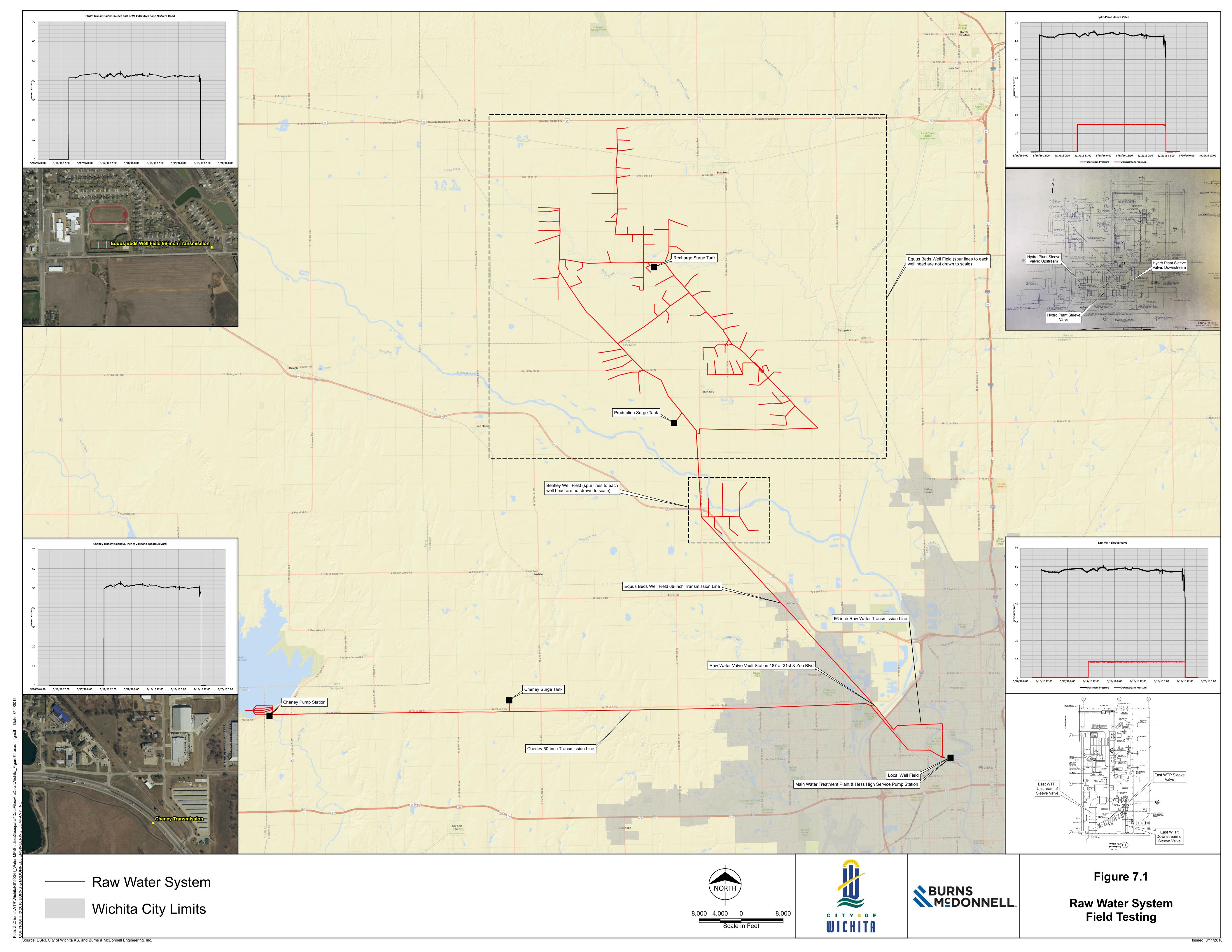
This section of the report discusses field testing, model calibration verification, and hydraulic analysis of the raw water system. As previous calibration efforts took place over 10 years ago, additional testing was conducted to recalibrate and verify the model to validate incoming pressures at the WTP. This is important as operational changes associated with the East WTP Improvements project are under design and need to be evaluated and verified with the model. Additionally, the model will be used assist in the design efforts of the East WTP improvements for raw water supply piping and hydraulic valves and general improvements in the future as applicable.

The first step in the calibration and verification of the model is field testing to collect flow and pressure data from the Cheney and EBWF supplies. Based on the field test data, the model is calibrated and verified. The calibrated raw water model is used to evaluate the following production scenarios:

- Scenario 1: determine the existing capacity of the EBWF and raw water transmission network without supply from Cheney. This production scenario evaluates the status of the valve at Station 187 (at 21st and Zoo Boulevard) under current conditions which maintains isolation from the Cheney transmission line at this location. There are two 66-inch transmission mains extending from 21st and Zoo Boulevard to the WTP from each supply. All water from the EBWF is conveyed through the existing northern transmission main to the WTP from 21st and Zoo Boulevard.
- Scenario 2: determine the capacity of the EBWF and raw water transmission network without supply from Cheney, similar to Scenario 1. However, this production scenario evaluates the status of the valve at Station 187 (at 21st and Zoo Boulevard) required to convey EBWF supply through both 66-inch transmission lines from 21st and Zoo Boulevard to the WTP.
- Scenario 3: determine the raw water supply available from the EBWF and Cheney with the status of the valve at Station 187 under current conditions (closed). This provides dedicated flow from both sources to the WTP where it is blended upstream of the sleeve valves.

7.1 Field Testing and Data Collection

Field testing was conducted on May 17 and 18, 2016 to collect data for model calibration verification. Field testing activities included pressure monitoring in the raw water transmission system recorded by data loggers. Two data loggers were positioned on transmission mains and four data loggers were placed on piping entering the WTP as shown in Figure 7.1 and described below:



- EBWF supply on 66-inch transmission main just east of W 45th Street N and N Maize Road near the railroad tracks;
- Cheney supply just southeast of the transition from the 60-inch to 66-inch transmission main near 21st and Zoo Boulevard. This location includes a blow off vault located in the shoulder of the east/south bound lanes:
- Upstream and downstream of the sleeve valve in the Hydro Plant building at the Central WTP; EBWF and Cheney supplies are blended upstream of the sleeve valve; and
- Upstream and downstream of the sleeve valve entering the East WTP; EBWF and Cheney supplies are blended upstream of the sleeve valve.

Other data collected from the City's SCADA system used for calibration and verification purposes is listed below:

- EBWF: combination of wells in operation, total EBWF flow, pressure at site M34 (EBWF), production surge tank level, and the recharge surge tank level;
- Cheney: pumps in operation, pump speed, pump station flow, discharge pressure, and Cheney surge tank level; and
- WTP: total flow, Central WTP flow, and East WTP flow.

7.2 Model Calibration Verification

Calibration is performed by adjusting, if needed, the Hazen-Williams coefficient, or C-value, assigned to pipe segments to simulate the recorded pressure and SCADA information under static conditions. The C-values are adjusted in the model within 5 psi of the field test pressures up to 80 psi; above 80 psi, the C-values are adjusted to simulate field conditions within 10 percent. Transmission mains with C-value adjustments included in the calibration are listed below and based on the field testing conducted in April 2016 and EBWF stress testing conducted in September 2005:

- 66-inch from EBWF to 21st and Zoo Boulevard (constructed in 1954, material unknown) increased from 115 to 120.
- 66-inch from 21st and Zoo Boulevard (northern transmission line, constructed in 2002, steel) increased from 115 to 130.

C-values were calculated based on the EBWF supply at 13.4 and 18.0 MGD from the tests in 2016 and at 47.5 MGD from the test in 2005 and suggest higher values than previous calibration efforts. Other variables in determining the calculated C-value included pipe length, pipe diameter, and frictional

headloss. Based on the calculations and pressures recorded during the field tests, these adjustments simulated field conditions and are representative of the pipe age and material.

The model developed from previous efforts has been updated and the scenario management structure simplified to include the two calibration tests and the three production scenarios described previously. Model updates include the current pump curves (Hydroflow pumps and Tesla motors) for all ASR Phase II wells, water pumping elevations based on the average drawdown from January, February, and March 2016 as provided by the City, and the specified pump elevation and column pipe lengths for all ASR Phase II wells; this data is included in Appendix F.

Modeling information maintained from the 2005 model includes the following:

- EBWF piping and transmission C-values not replaced in ASR Phase II;
- EBWF field tested pump curves (all wells not replaced in ASR Phase II); and
- C-value of 115 based on the pump station and transmission line testing and calibration efforts
 conducted on the Cheney transmission line in 2007; this low C-value is due to air accumulation in
 the transmission line as numerous air valves have been removed from service and Cheney surge
 tank is periodically operated with no water in the tank which allows air to enter the transmission
 main.

Model calibration results are listed in Table 7.1 and validate the C-values applied to the raw water system transmission mains. The model calibration adequately represents transmission pressure and WTP pressure recorded by the data loggers and total flow supplied by Cheney and the EBWF from SCADA information. Model results for flow from the EBWF wells in service during field testing are listed in Tables 7.2 and 7.3 below and are within +/- 3 to 10 percent of the 3-month average flow recorded in January, February, and March 2016; therefore, the flow contribution from the wells is also considered calibrated.

Table 7.1
Raw Water System Calibration

Test Data	est Data Cheney Pump Station				Equus Beds Well Field			21st & Zoo	45th & Maize	Central	Hydro Plant		East WTP			
& Model	Speed	Flow ¹	Pressure ²	Surge Tank	Flow	Prod. Tank	Rech. Tank	M34	Cheney	EBWF	WTP Flow	Upstream	Downstream	Flow	Upstream	Downstream
Results	%	(MGD)	(psi)	(ft)	(MGD)	(ft)	(ft)	(psi)	(psi)	(psi)	(MGD)	(psi)	(psi)	(MGD)	(psi)	(psi)
Test A	95	29.0	65	0.0	13.4	52.9	34.8	25	52	43	32.9	64	15	9.4	59	9
Model	78	28.7	46	fixed	13.7	fixed	fixed	27	55	42	fixed	62	11	fixed	61	8
Test B	97	30.0	65	0.0	18.0	53.0	35.0	25	50	42	38.7	63	15	9.4	58	9
Model	80	29.9	45	fixed	18.2	fixed	fixed	28	53	41	fixed	61	11	fixed	60	8

Notes:

- 1. Pump No. 2 on during each test at 95% in Test A and 97% in Test B.
- 2. Discharge pressure at Cheney PS cannot be accurately simulated in the model due to gravity conditions and/or air pockets entrained in the transmission main downstream of Cheney surge tank; therefore, more emphasis on PS flow, transmission main pressure, and WTP pressure is utilized for calibration verification and accurate simulations of the raw water supply contributions from the EBWF and Cheney at the WTP.
- 3. Bentley and local well fields were not in operation.
- 4. Test A: EBWF wells 2, 5, 9, 14, 17, 21, 25, 28, 32, and 46. Data recorded on 5/18/2016 at 10:07 AM.
- 5. Test B: EBWF wells 2, 5, 9, 12, 14, 17, 21, 25, 28, 32, 38, 46, and 54. Data recorded on 5/19/2016 at 7:33 AM.

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Table 7.2 - Test A: EBWF Pumping Comparison

Table 7.2 - Test A. Ebwi Tumping Companson									
Well Combination	Avg. Pump Flow ¹ (gpm)	Model Results (gpm)							
MR-2	779	818							
M-5	1,153	1,156							
M-9	845	712							
MR-14	1,034	1,100							
M-17	937	922							
M-21	1,200	1,125							
M-25	895	915							
M-28	769	706							
M-32	967	1,012							
M-46	402	356							

Notes

Table 7.3 - Test B: EBWF Pumping Comparison

Well Combination	Avg. Pump Flow ¹ (gpm)	Model Results (gpm)		
MR-2	779	813		
M-5	1,153	1,152		
M-9	845	705		
M-12	1,052	877		
MR-14	1,034	1,099		
M-17	937	919		
M-21	1,200	1,123		
M-25	895	910		
M-28	769	701		
M-32	967	1,010		
M-38	722	619		
M-46	402	354		
M-54	967	998		

Notes:

7.3 Hydraulic Analysis

Three production scenarios are evaluated with the model to determine the capacity of the raw water system under varying operating conditions of the valve at Station 187 and varying EBWF and Cheney supply contributions as previously discussed and summarized below.

- Scenario No. 1: determine the capacity of the EBWF supply and no supply from Cheney, the valve at Station 187 closed, and all flow through the northern 66-inch transmission main.
- Scenario No. 2: determine the capacity with the EBWF supply and no supply from Cheney, except the valve at Station 187 is open to convey EBWF supply through both the northern and southern 66-inch transmission lines from 21st and Zoo to the WTP.
- Scenario No. 3: determine the capacity of the EBWF and Cheney supplies with the valve at Station 187 closed, and flow from each supply through their dedicated transmission lines to the WTP where it is blended upstream of the sleeve valves.

The alignments described above represent how water can be conveyed from the EBWF and Cheney supply sources to the WTP. The construction of these transmission mains occurred at different times; a brief timeline of each is listed below:

- 60-inch from Cheney PS to 21st and Zoo Boulevard 1965;
- 66-inch from EBWF to WTP 1954;

^{1.} Data provided by City, from January, February, March 2016.

^{1.} Data provided by City, from January, February, March 2016.

- o For clarity, the portion of this line from 21st & Zoo Boulevard to the WTP is referred to as the "southern transmission main" in the previous paragraph.
- 66-inch from 21st and Zoo Boulevard to the WTP 2002;
 - For clarity, this portion is referred to as the "northern transmission main" in the previous paragraph.

The valve vault at Station 187 is located northeast of the railroad near 21st Street and Zoo Boulevard and includes piping/valving from the Cheney and EBWF transmission mains. The current valve status at Station 187 isolates the Cheney supply from the EBWF supply. Raw water from Cheney and the EBWF converge at the WTP upstream of the sleeve valves where both supplies are blended. As long as the valve status at Station 187 remains unchanged, the 60-inch Cheney transmission line transitions to a 66-inch transmission main at 21st and Zoo Boulevard and conveys raw water from Cheney to the WTP; this is referred to as the southern 66-inch transmission main. Raw water from the EBWF at 21st and Zoo Boulevard is conveyed to the WTP through the northern 66-transmission main. The alignment of the northern 66-inch transmission main is approximately 0.5 miles longer than the southern 66-inch transmission main.

Other factors and assumptions integrated in the production scenarios include the following based on current operational strategies provided by City staff:

- Benton string of wells (M29, M30, M31, and M32) are not available for production to the WTP, but available for Benton.
- No production from Bentley Reserve Well Field; conservative approach due the minimum streamflow requirement for use.
- EBWF recharge surge tank is isolated during production for ease of operation.

City staff provided the following historical operating information related to the production scenarios evaluated herein:

Historical maximum capacity pumped from Cheney was 72 MGD, but only for a short period of
time and is believed it was never delivered to the WTP as this flow rate was likely filling the
transmission main while air pockets and gravity portions of the pipe were exhausted, or what
could be exhausted.

- 60 MGD to 63 MGD is sustainable from Cheney, but flows over 65 MGD are not sustainable for extended periods of time due to overflows from Cheney surge tank, likely caused by air pockets that limit the capacity of the transmission main.
- EBWF can deliver approximately 68 MGD without Bentley wells M29, M30, M31, and M32; in September 2016, the EBWF and ASR system concurrently delivered approximately 60 MGD and 15 MGD respectively for about 1 hour.

7.3.1 Scenario No. 1: EBWF Supply Capacity w/Sta. 187 Current Status

Under Scenario No. 1, the EBWF supply and transmission capacity with the current valve status at Station 187 (isolates the EBWF supply from the Cheney supply) and no pumping production from Cheney PS is evaluated as illustrated in Figure 7.2. Under these conditions, the model results indicate approximately 80 MGD can be delivered from the EBWF as listed in Table 7.4; the EBWF surge tank is approximately 81 percent full and pressure upstream of the sleeve valves at the WTP is approximately 27 psi. The hydraulic gradient from the EBWF surge tank to the sleeve valves for the conditions described in this scenario is illustrated in Figure 7.3.

Review of Figure 7.3 shows the EBWF and Cheney supplies converging at the WTP, however upstream of the WTP, specifically upstream of Station 187, the Cheney system is positioned at a higher elevation than the EBWF system. The hydraulic gradient at 21st and Zoo Boulevard from the EBWF is approximately 1,382 ft (28 psi) at 80 MGD. The hydraulic gradient of the Cheney system at this location is 1,359 ft (18 psi). Upstream of this location, the Cheney transmission main results in negative pressures because Cheney surge tank is at higher elevations than the EBWF system.

• If a valve is closed on the Cheney 60-inch transmission line near 21st and Zoo Boulevard and a water level of 5 ft in Cheney surge tank is maintained, then the hydraulic gradient is approximately 1,520 ft (87 psi) upstream of the closed valve (on the Cheney system). Static conditions on the Cheney system yield the highest pressure in the 60-inch transmission main. The as-built plans indicate a minimum pressure of 100 psi for Class C pipe; therefore, static conditions should not exceed the pressure class of the transmission main.

The primary difference in this scenario compared to normal operating conditions, is no flow contribution from Cheney PS. Typically, at least one pump at Cheney PS is in operation and raw water supply is blended just upstream of the sleeve valves at the WTP. If the City is in a position/condition where Cheney supply is removed from service, then air could enter the Cheney system from the surge tank to elevations higher than 1,359 ft on the transmission main profile, which is the hydraulic gradient at the WTP from the EBWF. This includes the portion of the Cheney transmission main between the surge tank

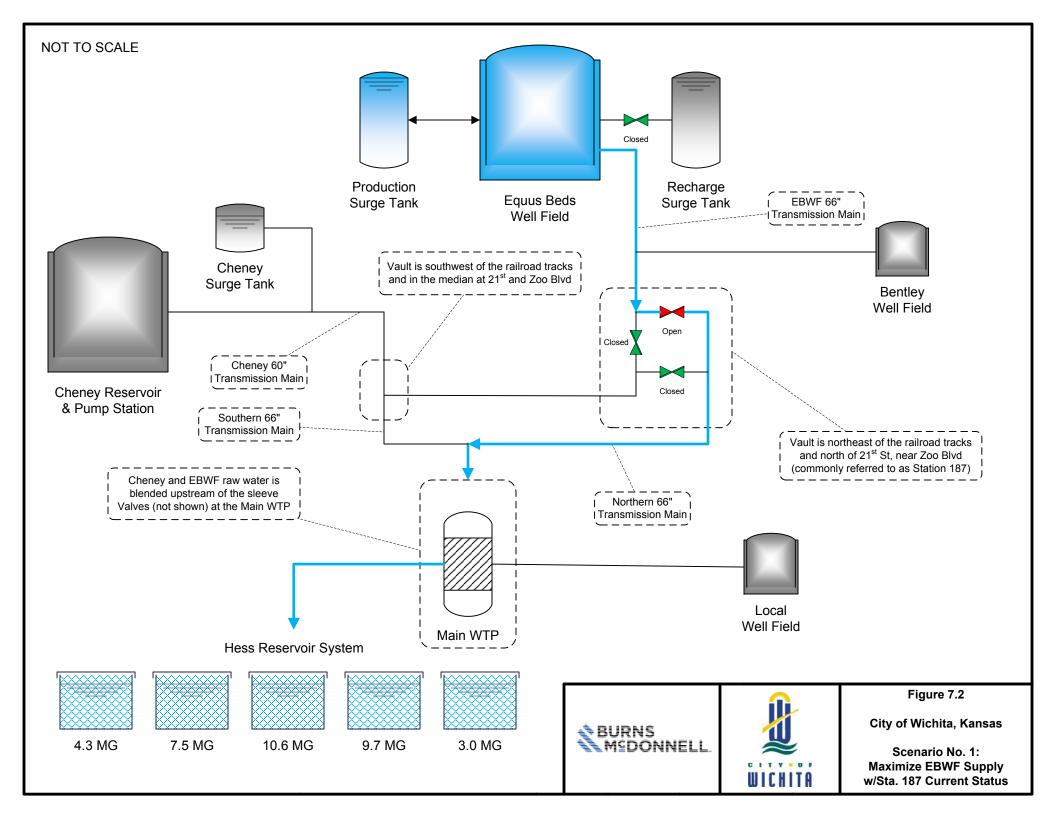


Table 7.4
Raw Water System: Model Results

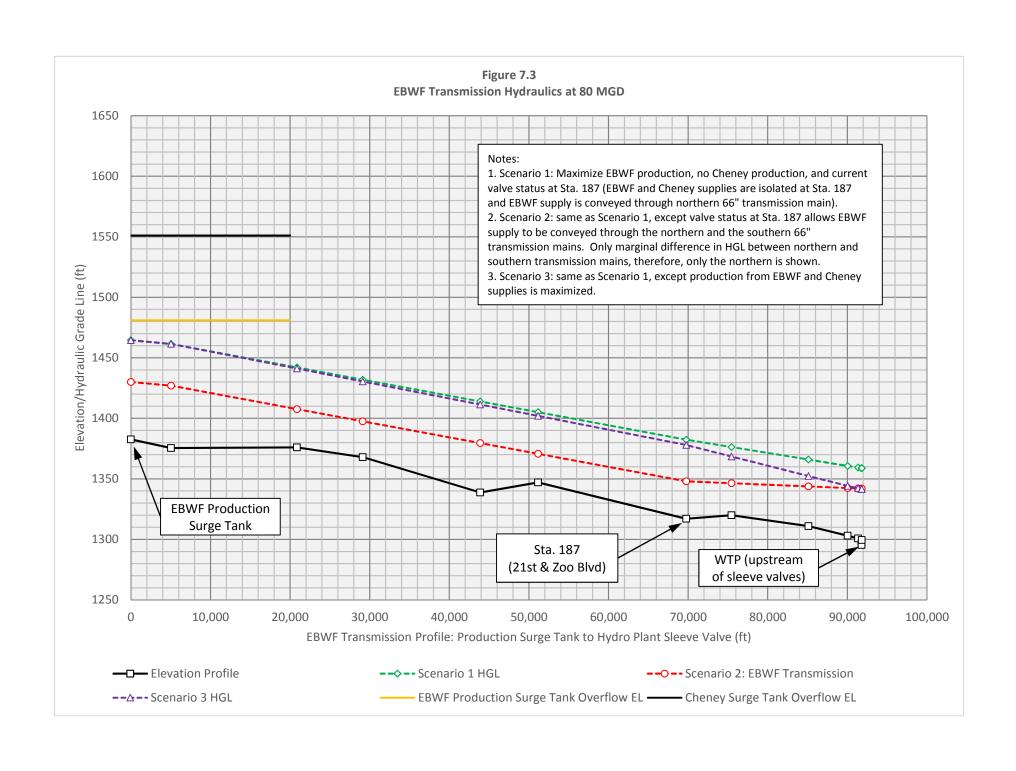
Facility	Scenario No. 1	Scenario No. 2	Scenario No. 3	East WTP Improvements Project			
racility	Scenario No. 1	Scenario No. 2	Scenario No. 3	Maximum Flow	Static Conditions	Low Flow	
EBWF Supply (MGD)	80	80	81	80	80	80	
EBWF Surge Tank (level, ft)	1,465	1,430	1,465	1,465	1465	1465	
EBWF Surge Tank (percent full)	82	42	81	81	81	81	
Station 187, EBWF (psi)	28	13	28	28	28	28	
Station 187 EBWF (HGL, ft)	1,382	1,348	1,381	1,382	1381	1381	
Cheney Supply (MGD)	0	0	79	80	0	20	
Cheney Surge Tank (level, ft)	empty	empty	1,522	1,522	1543	1541	
Cheney Surge Tank (percent full)	0	0	7	7	97	90	
Station 187, Cheney (psi)	18	same as "EBWF"	25	23	98	93	
Station 187, Cheney (HGL, ft)	1,359	same as "EBWF"	1,377	1,372	1545	1532	
WTP (MGD)	80	80	160	160	80	100	
WTP (psi)	27	20	27	see below	see below	see below	
WTP EBWF Supply (psi)	same as "WTP"	same as "WTP"	same as "WTP"	28	27	27	
WTP Cheney Supply (psi)	same as "WTP"	same as "WTP"	same as "WTP"	25	108	102	

Notes:

- 1. Conditions for Scenarios 1, 2, and 3, raw water is blended upstream of the sleeve valves at the WTP which has been the norm.
- 2. Conditions for East WTP Imrovements condition, raw water is blended downstream ov the sleeve valves at the WTP and each supply source has dedicated transmission; this condition provides the back pressure required to maintain water level in Cheney surge tank and enables the pump station and transmission line to deliver 80 MGD under full pipe flow conditions; however, under static and low flows from Cheney PS, the hydraulic gradient exceeds the operating design pressure of 80 psi along the southern transmission main (from Station 187 to the WTP).

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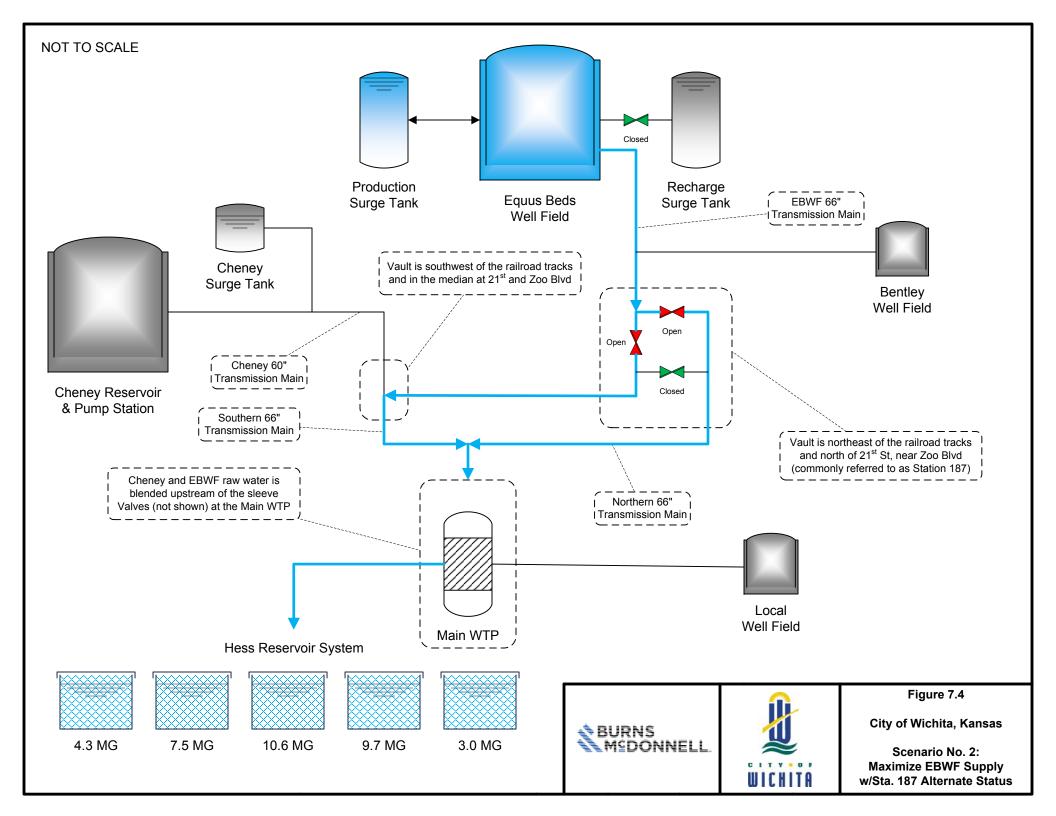
and approximately 1.8 miles east of 21st and Zoo Boulevard. Previous modeling efforts on Cheney PS and the 60-inch transmission main concluded air pockets limit the pumping capacity of Cheney PS, which is likely caused when the surge tank is empty, allowing air to enter the transmission main.

7.3.2 Scenario No. 2: EBWF Supply Capacity w/Sta. 187 Status Change

Under Scenario No. 2, the EBWF supply capacity with no flow from Cheney and an alternate, or open, valve status at Station 187 that allows flow through both 66-inch transmission mains to the WTP is evaluated and illustrated in Figure 7.4. Under these conditions, the model results indicate approximately 80 MGD can be delivered from the EBWF; the EBWF surge tank is approximately 42 percent full and pressure upstream of the sleeve valves at the WTP is approximately 20 psi. The hydraulic gradient at Station 187 is 1,348 (13 psi); differences between the hydraulic gradients for the northern and southern 66-inch transmission mains (from Station 187 to the sleeve valves) are marginal, therefore, only the northern transmission main is illustrated in Figure 7.3. This capacity is based on the groundwater pumping levels and the pump curves included in the model, it is not a capacity statement or conclusion on well hydrogeological performance.

Changing the valve status at Station 187 to convey EBWF supply through both 66-inch transmission mains effectively doubles the pipeline capacity from this location to the WTP and results in a lower headloss and operating gradient in the EBWF production surge tank. A lower operating gradient in the EBWF surge tank and transmission main is the only perceived benefit which may not be beneficial if the City desires more raw water storage in the EBWF. These results are applicable with the assumption that there is no supply contribution from the Cheney system.

Another model simulation was developed to determine the impact that Cheney PS has, with one pump on, under the condition where water is blended at Station 187. Under these conditions, Cheney PS reduced the EBWF supply capacity by approximately 53 percent, the remaining EBWF flow, approximately, 47 percent, fills the EBWF production surge tank. The model results indicate that the Cheney system could limit the EBWF supply contribution. A pressure sustaining valve on the Cheney transmission line (upstream of Station 187) is required to maintain a water level in the Cheney surge tank if raw water continues to blend upstream of the sleeve valves at the WTP. Therefore, a probable cost opinion for a pressure control valve is included in the capital improvements plan. The pressure control building is also used to lower the hydraulic gradient of the southern transmission main below the design operating pressure of 80 psi which can be eclipsed under low flows from Cheney PS; this condition is discussed further in Section 7.4.



7.3.3 Scenario 3: Raw Water Supply Capacities w/Sta. 187 Current Status

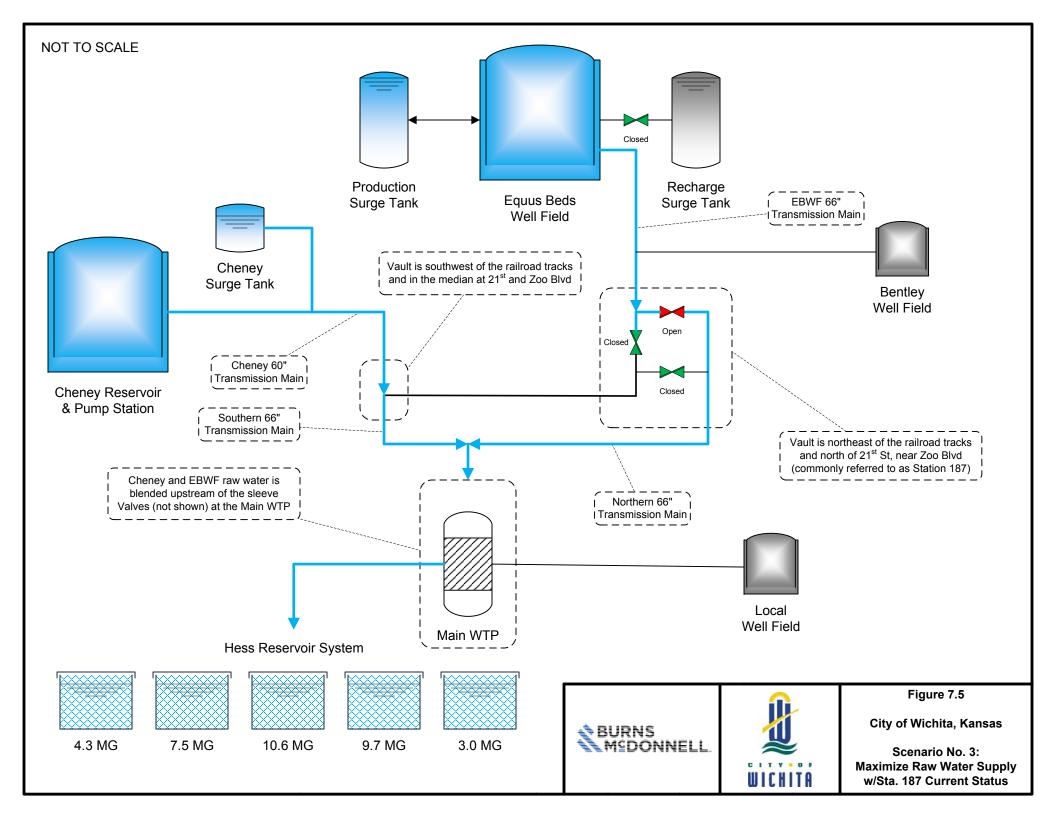
Under Scenario No. 3, the Cheney and EBWF supply capacities with the current valve status at Station 187 (closed) are evaluated and illustrated in Figure 7.5. Under these conditions, the model results indicate approximately 78 MGD can be delivered from the EBWF and 80 MGD from Cheney. Hydraulics for the EBWF system are illustrated in Figure 7.3 and Cheney system are illustrated in Figure 7.6. The hydraulic gradient from the EBWF system is similar to Scenario No. 1 and the pressure upstream of the sleeve valves at the WTP is approximately 27 psi. The hydraulic gradient at Station 187 for the Cheney and EBWF systems is approximately 1,377 ft (25 psi) and 1,381 ft (28 psi) respectively.

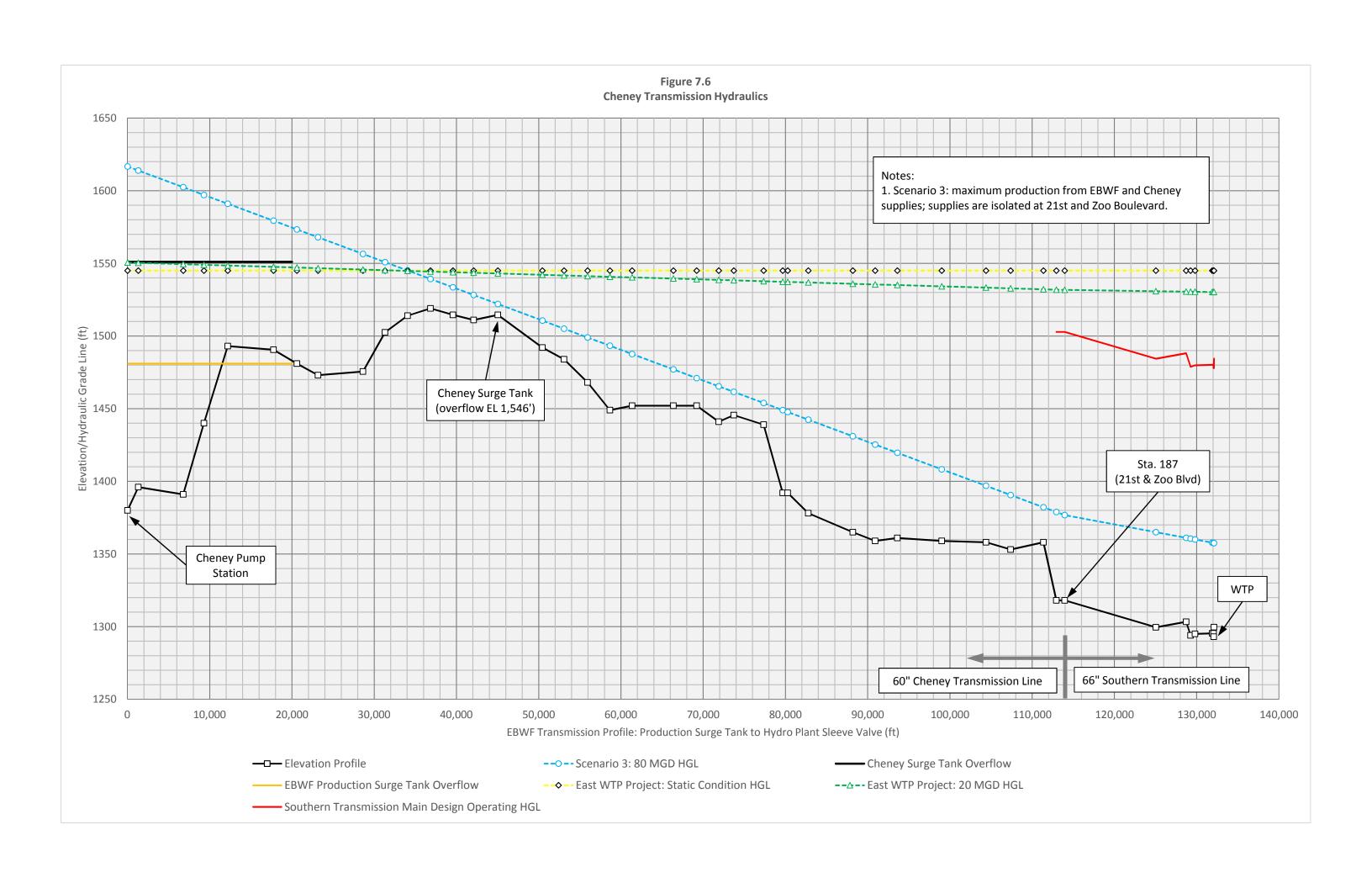
If Cheney surge tank levels drop below the base elevation of the tank and into the 60-inch transmission main, large quantities of air enter and create a gravity condition and/or air pocket formation in pressurized sections of the pipe. This limits the transmission capacity and ultimately the pumping capacity; the model only evaluates full pipe flow pressurized conditions. The presence of air pockets is reflective of the calibrated C-value for the transmission main; as air pockets are removed, then the C-value of the pipe should increase. If the air pockets are removed allowing full pipe flow and a water level is maintained in Cheney surge tank, then the model results indicate Cheney PS can deliver 80 MGD.

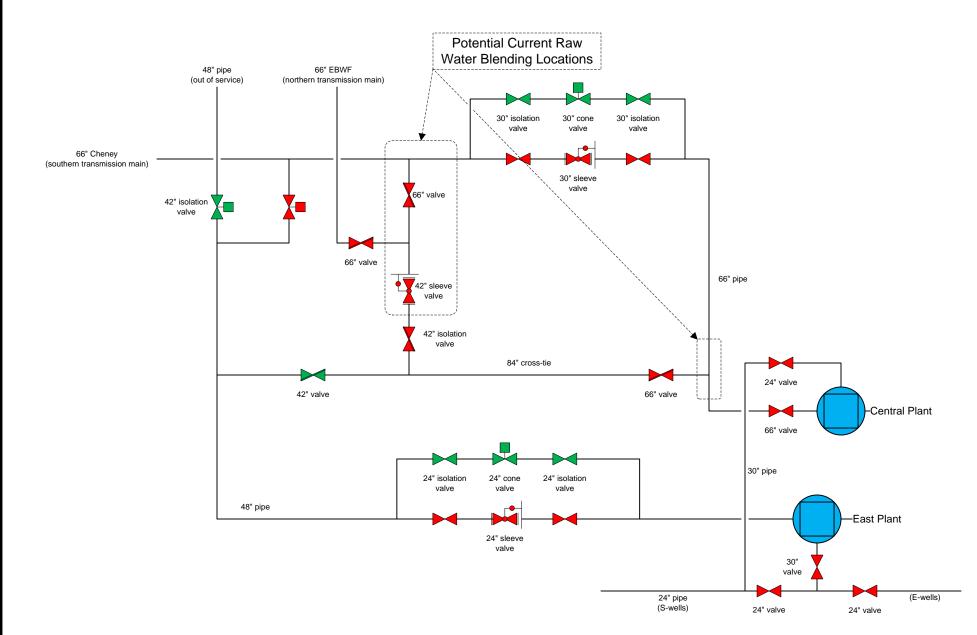
7.4 Impact of East WTP Improvements Project

The current mode of operation blends raw water from Cheney and EBWF supplies upstream of the sleeve valves as illustrated in Figure 7.7. The proposed mode of operation associated with the East WTP Improvements project isolates the supply systems from each other and each supply will have dedicated transmission to the new and existing sleeve valves (discussed in further detail in Section 8.0); raw water will blend downstream of the existing and proposed sleeve valves as illustrated in Figure 7.8. The proposed conditions are evaluated in the model to predict the impact on each supply system.

The hydraulic gradient for each system is similar to the results of Scenario No. 3; however, the major difference, or impact, in this mode of operation is the ability to maintain a constant water level in Cheney surge tank which also minimizes the potential to introduce air into the Cheney transmission main, allowing the Cheney system to deliver 80 MGD. When the Cheney and EBWF supplies cease blending upstream of the sleeve valves, the sleeve valves create "back" pressure on the transmission lines and could maintain a positive water level in Cheney surge tank. The model results indicate a constant water level of approximately 5 ft in Cheney surge tank can be maintained and does not result in excessive drafting or filling at 80 MGD. The hydraulic gradients at Station 187 on the EBWF and the Cheney systems under these conditions are approximately 1,372 ft (23 psi) and 1,382 ft (28 psi) respectively; the hydraulic gradients at the WTP for each system are approximately 1,352 ft (25 psi) and 1,359 (28 psi)







Notes:

- 1. Red valve status represents normally open.
- 2. Green valve status represents normally closed.

*BURNS MSDONNELL

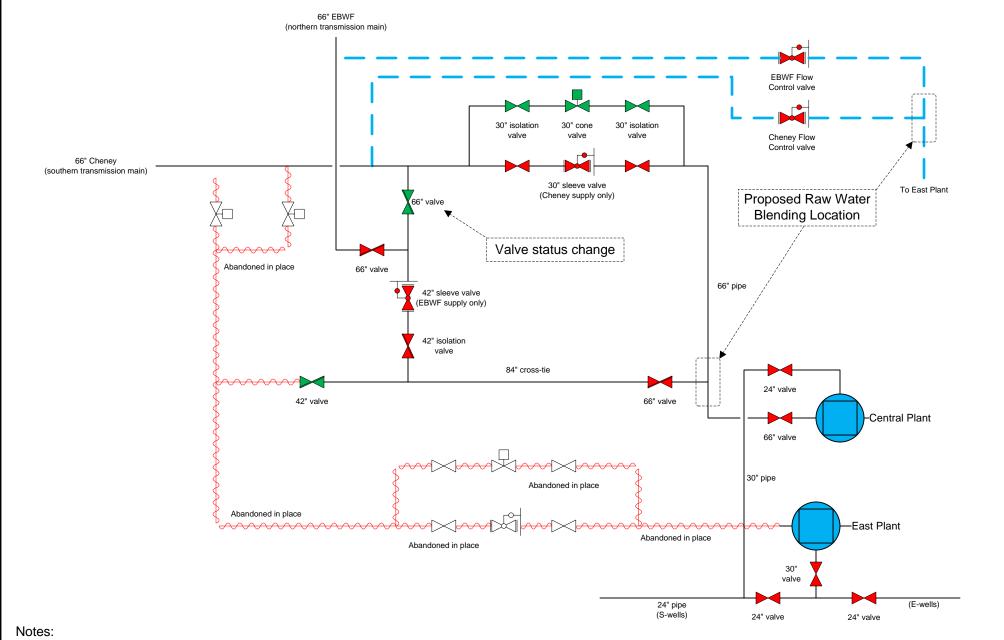


Figure 7.7

City of Wichita, Kansas

Existing Raw Water Blending & Valve Status

NOT TO SCALE



- 1. Red valve status represents normally open.
- $2. \ Green \ valve \ status \ represents \ normally \ closed.$
- 3. Dashed blue lines represent proposed piping changes associated with the East WTP Improvements project.

ABURNS MSDONNELL.



Figure 7.8

City of Wichita, Kansas

Proposed Raw Water Blending & Valve Status with East WTP Improvements

NOT TO SCALE

respectively. At high flows, these WTP pressures are acceptable, but under low flow or static conditions, the back pressure created exceeds the design operating pressure of the southern transmission main and City staff has report breaks when the pressure is increased at the WTP.

The maximum hydraulic gradient from the Cheney system occurs under static conditions (no pumps on) and the Cheney surge tank level just below the overflow elevation of 1,546 ft. The corresponding hydraulic gradients at Station 187 and at the WTP, with the operational changes imposed by the East WTP Improvements project in effect, are 1,545 ft (98 psi) and 1,545 ft (108 psi) respectively. If one pump is on at Cheney PS delivering 20 MGD, the hydraulic gradient at Station 187 and at the WTP is approximately 1,532 ft (93 psi) and 1,530 ft (102 psi). The hydraulic gradient between these locations represents the southern 66-inch transmission main which was originally the EBWF transmission main installed in 1954. When the northern 66-inch transmission main was placed in service in 2002, it conveyed EBWF supply from 21st and Zoo Boulevard (Station 187) to the WTP and Cheney supply was, and continues to be, conveyed by the southern 66-transmission main.

Review of the specifications for the original EBWF transmission main, which includes the southern transmission main, indicates a design operating pressure of 80 psi, which is below the anticipated pressures simulated by the model under static and low flow (one pump) conditions from Cheney PS with the "back pressure" induced by the sleeve valves at the WTP as a result of moving the raw water blending location downstream of the sleeve valves. The corresponding hydraulic gradient based on the elevation profile and the design operating pressure of 80 psi is also illustrated in Figure 7.6. The pressure control valve/structure discussed in Section 7.3.2 can also be used to lower the hydraulic gradient below the design operating pressure of the southern 66-inch transmission main under low flow conditions with the East WTP Improvements in effect. Back pressure would be provided by the pressure control valve to maintain water level in Cheney surge tank instead of the sleeve valves at the WTP under low flows from Cheney, or any flow condition that results in a hydraulic gradient greater than the design operating pressure of the southern transmission main. The pressure control building can be bypassed under higher flows that result in a hydraulic gradient below the design operating pressure; under this condition the sleeve valves at the WTP provide back pressure on the Cheney transmission mains to maintain a water level in the Cheney surge tank.

As a result of the operating pressure limitations of the southern transmission main, cost opinions for a pressure control building and a new redundant transmission main are included in the capital improvements plan. This is discussed in further detail in Section 8.1.

7.5 Conclusions and Recommendations

The results of the raw water model evaluation are consistent with previous calibrations and resulted in similar conclusions. The production scenarios evaluated herein conclude the following:

- Scenario No. 1: model results indicate the maximum production from EBWF is approximately 80 MGD with the EBWF surge tank approximately 80 percent full based on the well pump curves and groundwater pumping levels evaluated in the model.
 - Additional air will enter the pipeline through the Cheney surge tank to an elevation on the
 Cheney 60-inch transmission main equivalent with the EBWF hydraulic gradient.
 - Keeping Cheney PS in service (one pump minimum) is recommended to mitigate additional entrapment via Cheney surge tank.
 - o If Cheney PS has to be removed from service for an extended period of time (weeks or months), then the Cheney 60-inch transmission line should be closed or isolated upstream of Station 187 near 21st and Zoo Boulevard to mitigate additional air entrapment in the system.
- Scenario No. 2: model results indicate the maximum production from the EBWF is approximately
 80 MGD with the EBWF production surge tank approximately 42 percent full.
 - o If closure of the Cheney transmission line is required for an extended period of time (weeks or months), then the 60-inch transmission line should be closed or isolated upstream of Station 187 near 21st and Zoo Boulevard to mitigate additional air entrapment in the system;
 - o If low flows from Cheney PS (i.e. 1 pump on) are required to supplement raw water supply needs, the model results suggest the Cheney system limits the EBWF supply contribution by nearly half if the same wells remain in operation (approximately 42 MGD fills the EBWF production surge tank and only 38 MGD is conveyed to the WTP); eventually, production well will need to be turned off to stabilize escalating production surge tank levels.
- Scenario No. 3: under the current mode of operation, the model results suggest the maximum
 production from the Cheney system is approximately 80 MGD and the EBWF system is
 approximately 79 MGD; this assumes all air pockets are removed from the Cheney transmission
 main and has full pipe flow conditions.

Prior to construction of the East WTP Improvements project, the following raw water system tests are recommended:

• System Testing:

- O Confirm the operation and status of all air release / air vacuum valves (ARV) locations on the Cheney 60-inch transmission main. Replace ARVs that had been removed with re-sized valves and include a mechanism to minimize freeze potential in the ARV vaults. Determine locations to install additional ARVs.
- Isolate the Cheney and EBWF systems from each other at the WTP by closing the valve currently open between the 42-inch sleeve valve and 30-inch sleeve valve as shown in Figure 7.8; this condition simulates the proposed raw water influent changes associated with the East WTP Improvements project (raw water is blended downstream of the sleeve valves) and the conditions evaluated in Scenario No. 3. Supply from the EBWF would be conveyed through the 42-inch sleeve valve and supply from Cheney would be conveyed through the 30-inch sleeve valve. The Cheney system should remain below 80 psi from 21st and Zoo to the WTP (southern transmission main (66-inch diameter)) by operating at flowrates that do not result in higher pressures.
 - Note, City staff attempted this in early 2016 and suspect the backpressure may have resulted in water main breaks that followed. Therefore, this testing should occur after the East WTP improvements are in effect and implementation of a pressure control valve/structure to maintain full pipe flow in the Cheney transmission main and shear pressure below the design operating pressure.
 - Confirm the existing sleeve valves have adequate control over the range of flows that can be experienced and/or required under 80 psi on the Cheney system at the WTP;
 - If the valves do not have adequate control, then testing can occur after the East WTP improvements are in effect.
 - Confirm Cheney surge tank can maintain a constant and sustainable water level (or minimal drafting/filling rates);
 - If the existing sleeve valves do not have adequate control, then this may not be possible and should be assessed after the East WTP improvements are in effect and under flow conditions that do not result in pressure greater than 80 psi in the southern transmission main.
 - Assess hydraulic impact of the valve at Station 400 on the Cheney 60-inch transmission main. Isolating the Cheney and EBWF systems will increase pressure in the Cheney transmission mains because the Cheney surge tank is positioned at a higher elevation than the EBWF production surge tank; pressure can increase to 102 psi under low flow conditions (1 pump on at Cheney); under

static conditions (no flow from Cheney PS and a high water level in Cheney surge tank), pressure can reach 108 psi near the WTP. This exceeds the design operating pressure of 80 psi for the southern 66-inch transmission main.

- Operate/test each supply system under minimum and maximum flows under the condition described above (isolating the Cheney and EBWF systems from each other at the WTP), for example:
 - EBWF: 10 MGD to 20 MGD low flows and the maximum flow with all operational wells "on"; and
 - Cheney: low flow with one pump and maximum flow with four of the five pumps "on" (firm capacity) – or lowest flow that results in a pressure less than 80 psi at the WTP on the Cheney system.

City staff indicated the water main breaks are thought to be caused by increasing the pressure on the southern 66-inch transmission main (constructed in 1954) that conveys Cheney supply into the WTP. Pressure spikes, operational changes, pipe age, pipe material, aggressive soil conditions, inadequate thrust restraint, and joint type are all potential factors that contribute to water main breaks. If there is too much risk increasing the pressure in the southern transmission main than what has been historically experienced, then a redundant or a replacement transmission main from 21st and Zoo to the WTP or a pressure control station upstream of 21st and Zoo Boulevard on the 60-inch Cheney transmission line is recommended. This is addressed in further detail in Section 8.1 – Raw Water Supply portion of the Water Facilities Evaluation.

If the City considers implementing the conditions evaluated in Scenario No. 2 then field testing should be conducted for the supply contributions described below to validate the model results that indicated the Cheney system will potentially limit the EBWF supply:

- Low and constant supply (20 MGD to 30 MGD) from Cheney while gradually increasing EBWF supply to the maximum amount permissible (or without overflowing the EBWF Production surge tank) to assess limiting effects induced by Cheney;
- Low and constant supply (30 MGD to 40 MGD) from EBWF while gradually increasing Cheney supply to assess limiting effects induced by Cheney; and
- Limiting effects resulting from these test conditions described above would converge at similar points with respect to the maximum permissible flows from each source.

* * * * *

8.0 WATER FACILITIES EVALUATION

This section of the report assesses the capacity, water quality, regulatory, replacement, and redundancy-based needs and planned additions for the raw water, water treatment, and water distribution systems to meet the water demand projections and support the City's water supply plan. Limiting factors are identified and corresponding capital improvement projects are recommended to address the needs of each system.

8.1 Raw Water

The raw water system facilities evaluation addresses water supply planning and pumping/transmission needs. These evaluations are conducted to determine what improvements are required, when they are required, why they are required, and result in a capital improvement plan. The resulting improvements address a capacity issue tied to a demand trigger or are recommended for redundancy in conjunction with City staff opinions. Redundancy based improvements are intended to address reliability issues and capacity based improvements address the water supply planning needs to meet the projected maximum day demands. Due to the relationship between aquifer recharge and EBWF production, the capital improvements recommended to support water supply planning goals can carry both redundancy and capacity triggers.

8.1.1 Pumping and Transmission

The raw water model is used to evaluate pumping and transmission capacity and, based on the model results discussed in Section 7.0, no EBWF improvements are required. Raw water transmission from the Cheney and EBWF supplies have adequate capacity to convey approximately 160 MGD, but also require the previously recommended improvements to remove air from the Cheney transmission line. The transmission mains added in ASR Phase II allow the EBWF to convey upwards of 146 MGD if the well pumping capacity were installed.

The pumping capacity from the EBWF based on the current pump curves and groundwater levels indicates 80 MGD can be supplied; keeping in mind the model does not evaluate the operating condition of the wells or aquifer capacity. A well rehabilitation program is recommended, but is not considered a capital improvement, because well maintenance is essential to properly operate and sustain a reliable groundwater supply system. Water right 42824 provides conjunctive use with a maximum diversion rate of 80 MGD, therefore, additional water rights are not required.

The Cheney system has adequate pumping and transmission capacity if the air pockets are removed; however, increasing the pressure in the southern 66-inch transmission main from 21st and Zoo Boulevard

to the WTP (Cheney supply) could cause additional main breaks under low flows or static conditions from Cheney PS that result in operating pressures greater than 80 psi which is the design operating pressure.

The proposed operational changes imparted by the East WTP Improvements project will increase the pressure on this line at the WTP from 65 to 102 psi at 20 MGD from Cheney PS and up to 108 psi under static conditions (no pumps on at Cheney PS and Cheney surge tank nearly full). One option is a capital improvement that will enhance the redundancy and reliability of the Cheney supply while replacing an asset that is over 50 years old. These improvements include a 60-inch transmission main from Cheney PS to 21st and Zoo Boulevard to parallel this 50-year old line and a 66-inch transmission main from the EBWF to the WTP to parallel the 60-year old line. The parallel raw water transmission mains serve the following purposes:

- Transmission redundancy for both water supply sources;
- Removes risk of increasing pressure in the existing southern 66-inch transmission main that could potentially cause water main breaks;
- Allows the isolation valve separating the Cheney supply from the EBWF supply at the WTP to remain normally closed; this eliminates blending potential upstream of the WTP sleeve valves and supports the primary objective of the East WTP Improvements project which calls for 100 percent groundwater treatment up to 80 MGD if surface water from Cheney is unavailable; and

A condition assessment of all raw water transmission mains is recommended before planning and engineering of the redundant/parallel transmission improvements to determine the following:

- Anticipated remaining useful life of each transmission main;
- Defect detection, leaks, air pockets, pipe material changes, damaged pipes, pipe stress, offset
 joints, cracks, corrosion, etc.; and
- Develop triggers, advantages, and disadvantages to determine if reinvestment in the existing
 transmission main, or sections thereof, is recommended or if new parallel transmission is
 recommended based on end goals, remaining useful life, and anticipated operating conditions.
- Determine whether or not it is better to replace the southern 66-inch transmission main (Cheney supply) and install a new transmission main from Cheney PS to the WTP.

An alternative to a redundant 66-inch transmission main from 21st and Zoo Boulevard to the WTP (Cheney supply) is providing pressure control on the 60-inch Cheney transmission main as previously recommended. A pressure control valve or structure upstream of the 21st and Zoo location will maintain

water level in the Cheney surge tank and shear pressure below the design operating pressure (80 psi) of the southern 66-inch transmission main under low flows; this would alleviate the concern of increased pressures under low flow conditions from Cheney PS in conjunction with the operational changes imparted by the East WTP Improvements project. Under static conditions, with no flow from Cheney PS, the pressure control structure should include adequate isolation (valves) that maintain a positive water level in Cheney surge tank; isolation valves, coupled with vacuum breaker and air release, also removes the static pressure head from Cheney surge tank on the southern 66-inch transmission main. If the pressure control structure and isolation valves are positioned near 21st and Zoo Boulevard, then under static conditions with isolation in effect, the pressure at the WTP is approximately 10 psi to 15 psi.

The pressure control building can be implemented, thereby delaying the 66-inch redundant transmission main improvement from 21st and Zoo Boulevard to the WTP (Cheney supply); but since this transmission main also provides redundancy for the EBWF supply, the pressure control building is still required if the Cheney supply is conveyed through the existing southern 66-inch transmission main. Therefore, cost opinions for the pressure control building and the redundant 66-inch transmission main from 21st and Zoo Boulevard to the WTP are both included in the capital improvements plan. Since the East WTP Improvements project is currently under design and would be operational before implementing a redundant 66-inch transmission main from 21st and Zoo Boulevard to the WTP, the pressure control building has a higher priority with a hydraulic trigger functioning to maintain pressure less than 80 psi.

In the short term, capital improvements for the Cheney system have a higher priority until the East WTP Improvements are complete because the EBWF production capacity far exceeds the current groundwater-only treatment capability of the WTP; so enhancing the reliability of the Cheney system takes priority. After the East WTP Improvements are complete, the EBWF transmission mains are a higher priority than the Cheney 60-inch redundant transmission main, as this water supply source is more reliable under drought conditions. The EBWF is not only a more reliable supply, but is also more a robust supply source as it is comprised of over 60 individual wells as opposed to a single lake, intake and pump station like the Cheney system. Improvements can be re-prioritized if any item of infrastructure reaches a point where its condition degrades and continued use is an operational concern.

A summary of the prioritization and triggers for raw water transmission improvements is listed below:

- Top priority:
 - Pressure control valve or structure implement before the East WTP Improvements
 project requires shifting the raw water blending location from upstream of the sleeve

- valves to downstream of the sleeve valves. The trigger for this improvement is to support Cheney system hydraulics and maintain operating pressure below 80 psi in the southern 66-inch transmission main.
- Note, this is designated a top, or higher priority, over replacing the southern 66-inch transmission main from 21st and Zoo Boulevard to the WTP transmission main based on cost and construction time.
- Low priority further prioritization requires a condition assessment:
 - o New 66-inch transmission from EBWF to 21st and Zoo Boulevard.
 - Note, existing transmission remains in service.
 - New 66-inch transmission from 21st & Zoo Boulevard to the WTP.
 - The City should also consider replacing the existing transmission main to maintain full transmission redundancy for the EBWF and Cheney supplies; for clarity, this option requires two new transmission mains.
 - For the purposes of this master plan, only one new transmission main will be included in the CIP.
 - o New 60-inch transmission from Cheney PS to 21st and Zoo Boulevard.
 - A 66-inch diameter can be considered if the hydraulic impact on the Cheney PS pumps and surge tank levels provides better operational value to the City and its operators.
 - Note, the existing transmission can remain offline and used when needed, for example under emergency conditions (main break) or for operational flexibility. This would provide transmission redundancy for the Cheney supply between the PS and 21st and Zoo Boulevard.

8.1.2 Supply Planning and Facility Needs

Water supply planning recommendations for the EBWF production and recharge goals align with the City's water supply plan with drought conditions and demand projections established in the Water Resources Plan. They also align with the 2014 recommendations included in the Enhanced ASR report (by Burns and McDonnell). The Water Resources Plan is based on an average day demand projection of 84 MGD by 2060 (or 72 MGD based on a 1 percent drought and with 35 percent conservation in effect); an average day demand of 84 MGD corresponds to a maximum day demand of approximately 160 MGD if extrapolated beyond the 2045 planning period. The capital improvements recommended to support a 160 MGD demand are discussed below.

8.1.2.1 Recharge Recovery Wells

Testing conducted by City staff in October 2016 indicated a maximum EBWF production capacity of 55 MGD. In a subsequent test, the maximum capacity of the EBWF 66-inch transmission main pipeline was estimated at approximately 70 MGD. An estimated 20 RRWs with a minimum production capacity of 20 MGD and goal of 30 MGD are needed to achieve an overall EBWF capacity of 70 MGD. This assumes each well can produce 1,000 gpm. These wells would also provide additional locations to recharge the aquifer and spread recharge across the entire EBWF. Assuming 60 MGD is supplied by Cheney and an EBWF supply of 70 MGD, the total raw water supply is approximately 130 MGD meeting the year 2045 demand projection.

The EBWF supply is based on the following:

- Current conservative EBWF production capacity is 50 MGD;
 - A pipeline capacity of approximately 79 MGD from the EBWF was tested by the City in October 2016.
 - A well capacity of approximately 50 MGD was also tested by the City.
- Assumes 10 percent of wells (existing or proposed/new RRWs) are temporarily out of service for maintenance or rehabilitation efforts;
- New RRW production capacity ranges from 700 gpm to 1,000 gpm; and,
- Assumes all wells are properly maintained to provide current or improved capacities.

It should be noted that if 1,000 gpm per well is not attainable, the number of wells required will increase. For example, if an average capacity of each well is 500 gpm and 10% are assumed to be out of service, the number of required wells would be 32.

8.1.2.2 Bank Storage Wells

Based on the information and evaluation included in the Enhanced ASR Report, bank storage wells have the capability to provide approximately 3,700 MG/year of recharge water to the EBWF. Land availability at the time of the Enhanced ASR report assumed nine bank storage wells can provide up to an additional 15 MGD when flow in the Little Arkansas River is above baseflow. However, based on the ASR regulations, flow is not always available, as bank storage diversion is only permitted from the Little Arkansas River during above baseflow periods. Furthermore, the potential for elevated river levels above baseflow diminish during drought conditions.

Bank storage wells provide an added benefit when operated in conjunction with side stream storage (or an above base-flow holding reservoir). Side stream storage can be filled from the intake or bank storage wells and hold additional water during an above baseflow event to expand the volume of water for recharge. The ability to use bank storage wells to fill side stream storage at streamflow less than 65 cfs further extends recharge duration and increases the volume of water recharged. The existing ASR intake facility has physical withdrawal restrictions below 65 cfs; bank storage wells can capture additional diversions during above baseflow events.

8.1.2.3 Recharge Basins

Recharge basins provide operational flexibility during recharge events and provide a mechanism to recharge large volumes of water at a single site. They also provide additional locations to recharge water during start-up of the ASR Surface WTP before initiating recharge through RRWs. Detailed hydraulic and hydrogeological studies are required to evaluate each potential recharge basin site as not all sites are suitable for a recharge basin. For the purposes of this report, it is recommended that one recharge basin be installed for every 15 MGD of aquifer recharge wells. Based on the proposed 20 RRWs with a capacity of 20 to 30 MGD, two recharge basins are included in the CIP.

8.1.3 Raw Water Facilities Summary

A summary of the capital improvements and corresponding opinions of probable cost, implementation year, and trigger for the raw water system is listed below – prioritization is identified by the recommend completion dates:

- Pressure Control Building: includes parallel sleeve valves, block building, interior and buried 30-inch piping and valves, buried 60-inch motorized BFV (also used for transmission isolation under static conditions), vacuum breaker valves, mechanical, and electrical. The trigger for this improvement is hydraulic and recommended for completion before the East WTP Improvements (tentatively estimated for completion 2019) project requires shifting the raw water blending location from upstream of the sleeve valves to downstream of the sleeve valves. The trigger for this improvement is hydraulic and recommended for completion before 2019.
 - The opinion of probable cost is \$3.2 million.
- Bank Storage Wells: includes nine bank storage wells, raw water distribution piping, power/electrical, SCADA, and a surface WTP bypass. The trigger for this improvement is redundancy and capacity and recommended for completion by 2020.
 - o The opinion of probable cost is \$12.4 million.

- Recharge Recovery Wells: includes 20 RRWs, building (pumps and piping), electrical, SCADA, site work, power distribution, and raw water piping and associated transmission network to connect to the existing system; referred to as ASR Phase III in other reports. The trigger for this improvement is redundancy and capacity and is recommended for completion by 2022. Initiation of property acquisition is recommended in the second quarter of 2017 to assure project completion by 2022.
 - The opinion of probable cost is \$56.4 million.
- Recharge Basins: includes 2 recharge basins with 15 MGD recharge capacity each. The trigger
 for this improvement is redundancy and capacity and is recommended for completion by 2022.
 - The opinion of probable cost is \$3.4 million.
- EBWF Transmission Main: includes a 66-inch diameter transmission main from the EBWF to 21st and Zoo Boulevard and a 36-inch connection to the existing 48-inch Halstead transmission main. Other connection sizes can be considered depending on the City's long term plan for the 48-inch transmission main if restored. The trigger for this improvement is redundancy; completion date dependent upon a condition assessment.
 - The opinion of probable cost is \$91.1 million.
- Cheney Transmission: includes a parallel 60-inch to the existing 60-inch transmission main from Cheney PS to 21st and Zoo Boulevard and a parallel 66-inch transmission main from this location to the WTP. The trigger for this improvement is redundancy; a completion date is dependent on the results of a condition assessment.
 - The opinion of probable cost is \$151.8 million.

The City's Water Resources Plan, dated December 2015, presented to City council also recommended bank storage wells, rehabilitation of existing wells for recharge capability, and construction of new RRWs to address drought supply needs. Other possible future improvements for reliability and redundancy, also included in the Water Resources Plan, included a new Northwest WTP, parallel transmission from the EBWF, parallel transmission from Cheney, and rehabilitation of the existing raw water lines and WTP.

The current City capital improvements listed below are included in this master plan in addition to the system testing recommendations indicated in Section 7.0:

- Current City CIPs:
 - o Cheney 60-inch transmission main ARV improvements.
 - Improvements recommended prior to the East WTP Improvements Project.

- Note, removing air pockets in the Cheney 60-inch transmission main may take considerable time, possibly months; and
- Construction Phase of the East WTP Improvements Project.

• Testing:

- Operation of existing ARVs on the Cheney 60-inch transmission main and the 66-inch southern transmission main from 21st and Zoo Boulevard to the WTP.
- Isolate the Cheney and EBWF supplies upstream of the sleeve valves at the WTP to determine the operational control is adequate over a range of flows (EBWF supply controlled by 42-inch sleeve valve and Cheney supply controlled by 30" sleeve valve).
 - This should be done after the East WTP Improvements and pressure control valve/structure CIP are implemented.
- Condition assessment of raw water transmission installed before 1960 to establish anticipated remaining using life and develop a more in depth rehabilitation or replacement schedule.

8.1.4 EBWF Groundwater Quality

Water obtained from the City's well field in the Equus Beds is generally of good quality for municipal water supply. Currently, water rights and pumpage for agricultural and municipal use exceed the natural recharge rate. While current groundwater levels are relatively high, historic excessive pumpage has resulted in lower static water levels, increasing the gradient toward the EBWF from the south, north and west. A higher groundwater gradient increases the rate of migration of high-chloride water from the Arkansas River to the southwest, upwelling of saltwater from the Permian bedrock below the Arkansas River, and by oil field brine from the Burrton area to the northwest.

The Arkansas River receives saltwater discharge from Permian formations upstream of Hutchinson, Kansas, resulting in high-chloride concentrations in the river water. The concentration of chlorides in the river water has a median value of 630 mg/L (Myers, 1996). Concentrations of chlorides as high as 4,000 mg/L (Whittemore, 1990) are found in the Permian bedrock near the Arkansas River. The Burrton area contains groundwater with chloride concentrations as high as 9,000 mg/L.

Multiple groundwater modeling studies have been conducted (Myers, 1996, Pruitt, 1993, and Burns & McDonnell, 1994) that demonstrate the interaction of the Arkansas River with the Equus Beds Aquifer and the impact of high-chloride migration into the aquifer. The modeling studies indicate that if no action were taken to remediate or control these plumes, the chloride levels would be as high as 400 mg/L in the

southern part of the well field and as high as 300 mg/Lin the extreme northwest part of the well field by 2049. Since Wichita's existing WTP cannot remove chlorides, the potential for chloride migration into the EBWF has the potential to affect future treatment processes.

8.2 Existing Water Treatment Facilities

The Main Water Treatment Plant (MWTP) is divided into two sections; the Central Plant and the East Plant. Both plants include aeration, rapid mix, flocculation, sedimentation, filtration and disinfection. The filtration facilities are shared between the two plants, as are chemical feed systems, solids handling facilities, and disinfection facilities. These processes and convergence points are illustrated in Figure 8.1.

The Central Plant has a rated capacity of 130 MGD and includes two treatment trains; each train has flocculation, primary sedimentation, and secondary sedimentation. Both trains are similar and can operate in parallel or one at a time. If one train is out of service, the capacity of the Central Plant is reduced to 65 MGD.

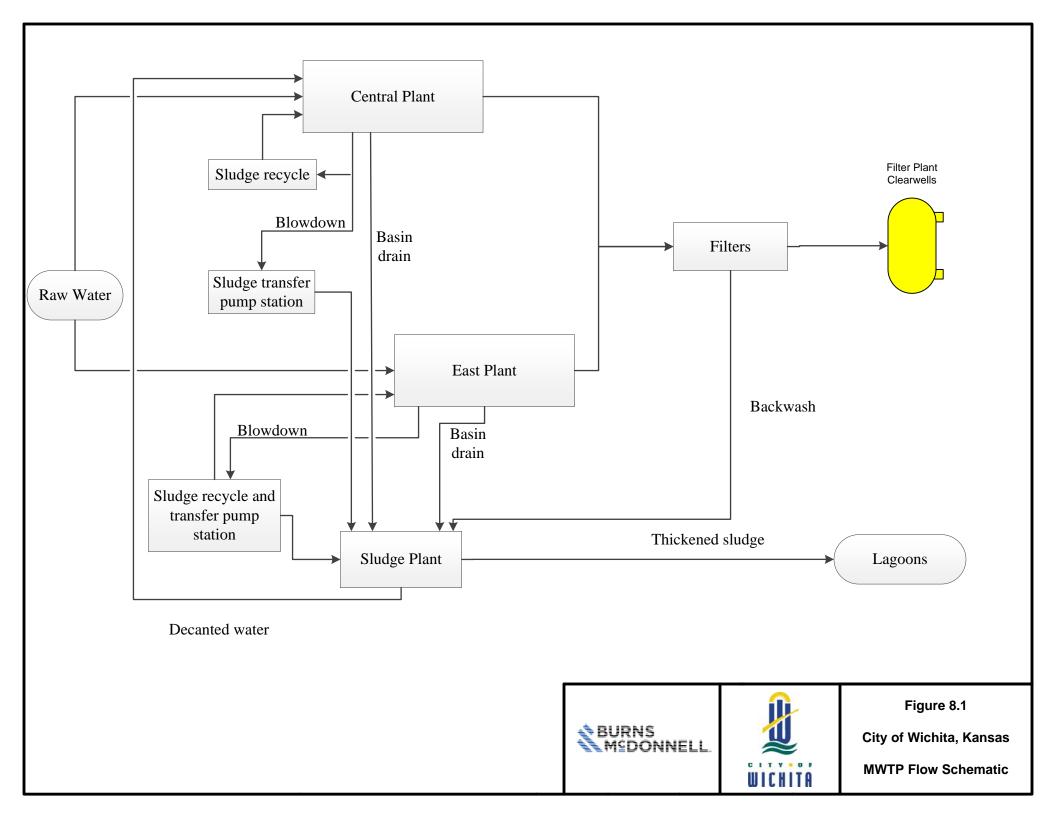
Currently, the East Plant has a rated capacity of 30 MGD and includes a flocculation basin, two primary sedimentation basins, and one secondary sedimentation basin. The western primary sedimentation basin is rated at 10 MGD and the eastern primary sedimentation basin is rated at 20 MGD. Since the East Plant does not have redundant flocculation or secondary sedimentation, an outage of either reduces the East Plant to 0 MGD. An equipment outage or planned maintenance of the primary sedimentation basins reduces the East Plant capacity to either 10 MGD or 20 MGD, depending on which treatment train is not operating.

8.2.1 Rated vs. Operational Capacity

As stated above, the rated capacities of the Central and East plants are 130 MGD and 30 MGD respectively; however, the City has indicated the operational capacity of these facilities is less. The rated and operational capacities of the treatment processes are listed below in Table 8.1.

Process Area	Central Pla	nt (MGD)	East Plar	nt (MGD)	Combined (MGD)		
Process Area	Rated	Actual	Rated	Actual	Rated	Actual	
Clarification/Softening	130	100	30	25	160	125	
Filtration	N/A	N/A	N/A	N/A	160	Unknown	
Disinfection and Chemical Feed	130	130	30	30	160	160	

Table 8.1 – WTP Capacity Limitations



The combined clarification/softening capacity of 125 MGD is the limiting factor in achieving a total rated treatment capacity of 160 MGD. It should be noted that while the actual filtration capacity of the plant is listed as unknown above, the total filtration capacity with all filters in service is believed to be above 125 MGD (as further discussed in Section 8.2.5). It should also be noted that the firm capacity (with one filter out of service) is approximately 119 MGD which would result in a treatment capacity deficit by 2020; however, it is assumed that during peak usage, staff would ensure that all filters are made available and therefore the maximum capacity is determined with all filters in service.

This flow rate of 125 MGD is adequate to meet the current 2016 and 2020 planning period maximum day demands of 118 MGD and 120 MGD respectively; however, a treatment capacity deficit occurs in the 2035 and 2045 planning periods based on maximum day demands of 127 MGD and 128 MGD respectively. This and other treatment processes are currently being upgraded in the East Plant Improvements project, therefore, capital improvements associated with clarification/softening capacity are not included in this master plan.

The disinfection and chemical feed systems are designed to treat 160 MGD, which meets the year 2045 planning period. The existing systems are functional, but aging, and are currently being upgraded to match a capacity of 160 MGD; therefore, capital improvements associated with chemical feed systems are not included in this master plan.

Another limiting factor in treating the combined rated capacity of 160 MGD is the shared filtration process between the Central and East plants. The limiting factors associated with the filtration process include condition of the filter underdrains and media, filter backwash supply, filter backwash flow rate, filter backwash disposal, and filter loading.

The capacity portion of the evaluation compares filter capacity with the water demand projections and rated treatment capacity listed below to identify capacity-based limiting factors in the filtration process and to assess each process individually (where applicable):

- 2016 Maximum Day Demand Projection: 118 MGD;
- 2045 Maximum Day Demand Projection: 128 MGD; and
- Rated Filter Capacity: 160 MGD.

8.2.2 Limiting Factor: Hydraulic Bottleneck

A desktop analysis identified a hydraulic bottleneck limiting the supply within the filter influent flume separating Filter No.'s 1 through 6 from Filter No.'s 7 through 14 as illustrated in Figure 8.2. The

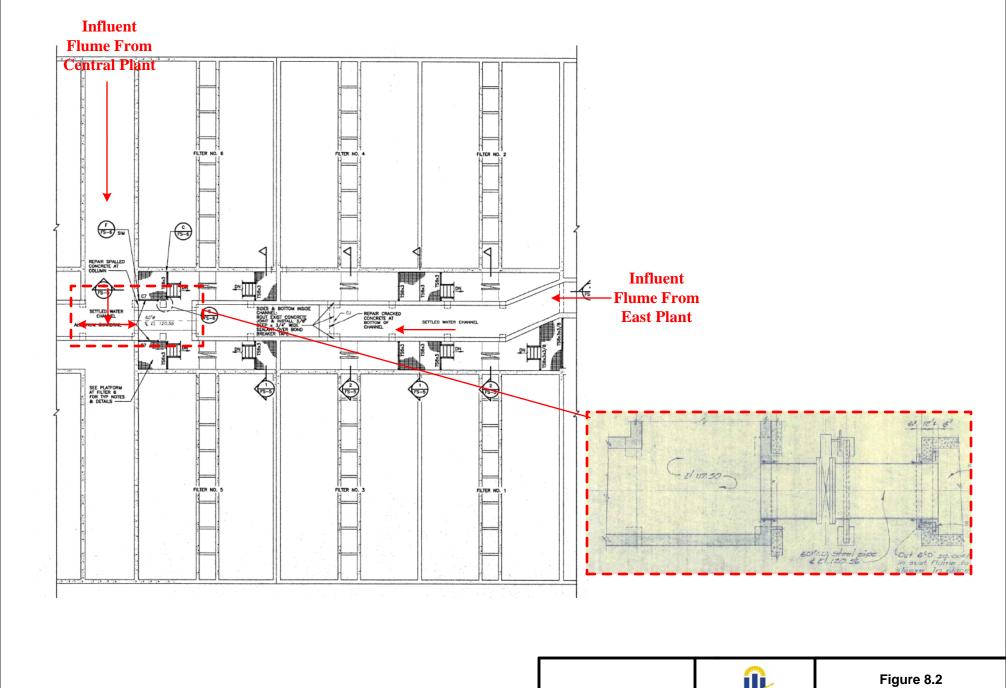






Figure 8.2

City of Wichita, Kansas

Filter Hydraulic Bottleneck

hydraulic bottleneck may be occurring at a pipe/valve transition within the square flume or may be the result of a build-up of solids, likely calcium carbonate, in the influent piping, valves, and flume. The reduced area of the pipe at the transition and additional friction losses through the valve are potential causes of excessive headloss. Furthermore, supply from the Central and the East plants feeding the flume do not provide hydraulic similitude that would otherwise provide an equal distribution to each filter. While the extent of this limitation has not been precisely determined for the purposes of this report, it is currently being evaluated in the East Plant Improvements project and will be addressed in that project if necessary; therefore, capital improvements associated with the restriction are not included in this master plan.

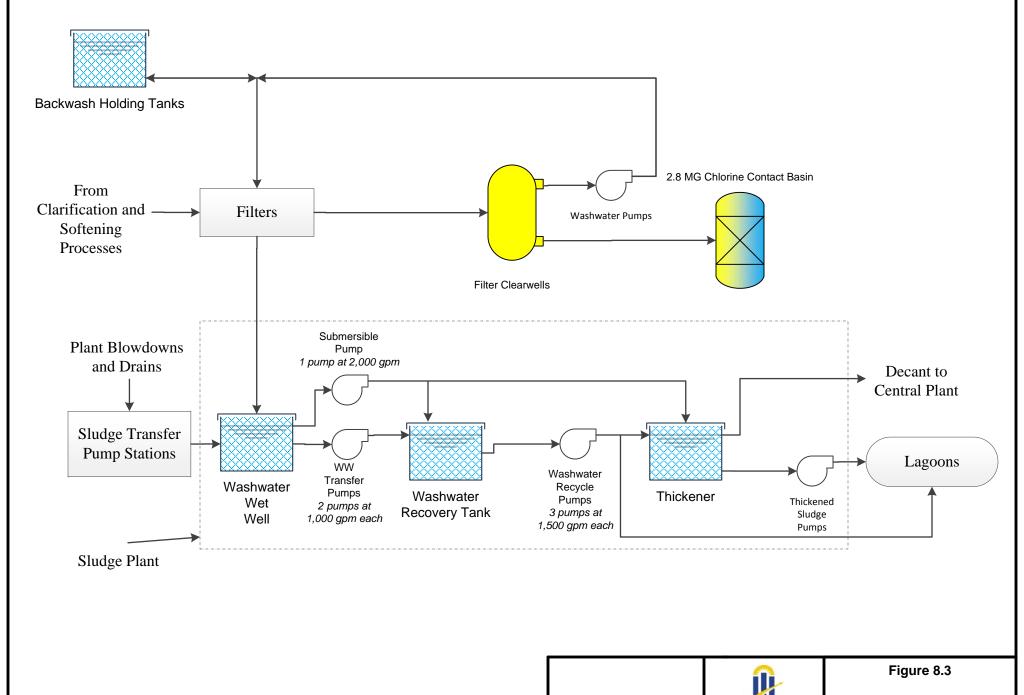
8.2.3 Limiting Factor: Filter Backwash Flow Rate

The design backwash flow ranges from 7,000 gpm to 28,000 gpm and is pumped from storage tanks above the treatment facilities. The equivalent backwash volume ranges from 85,000 gallons to 100,000 gallons per backwash cycle. Storage volume for backwash supply is adequate, but the refill rate for the equalization volume (depleted storage due for backwash cycles) is approximately 6,000 gpm, therefore, the number of filters that can be backwashed in a 24-hour period is limited. While this limits the capacity of the plant, it is not preventing the plant from meeting flows necessary to meet the 2045 demands.

The filtration capacity is also limited by the ability to backwash and properly clean the filters. The 2016 Filter Evaluation, by Burns & McDonnell, concluded the current backwash flow rates do not adequately clean the filters and called for recommendations to increase the flow rate from 23,000 gpm to between 29,000 and 31,000 gpm. Other recommendations in the study called for backwash water chlorination and filter underdrain replacement. It is important to note that better cleaning of the filters can increase filtration capacity; consequently, it also places a higher loading on the backwash supply system. Capital improvements for these recommendations and corresponding opinions of probable costs are summarized at the end of this section.

8.2.4 Limiting Factor: Filter Backwash Disposal

Backwash waste is conveyed to the residuals handling facilities, also known as the sludge plant, as illustrated in Figure 8.3. In addition to normal backwash waste rates, the filter influent and backwash valves leak and contribute a significant amount of excess flow to the sludge plant. The capacity of the sludge plant is not sized to handle the excess flow contribution imparted by the filters in addition to normal backwash waste flows. A design-build project was awarded September 2016 for these improvements; therefore, no CIP is included in this report.







City of Wichita, Kansas

Filter Backwash and Sludge Plant Schematic

The remainder of this section evaluates the sludge plant capacity based on the assumption that the filter valve replacements are complete. The required capacity of the sludge plant includes backwash waste and solids transfer from the clarification facilities. The corresponding amount of sludge produced based on the demand projections is summarized in Table 8.2 below:

Table 8.2 - Plant Flows and Backwash Quantities

Total Plant Flow¹ (MGD)	160	128	118
Backwash + Solids Waste Flow (MGD (gpm))	7.3 (5,048)	5.7 (3,943)	5.2 (3,635)

Notes:

The volume of the washwater wet well is approximately 60,000 gallons and is the first of three basins positioned in series for holding wastewater which is transferred by a series of pumps; the second basin is the washwater recovery tank. A submersible pump in the washwater wet well delivers waste either to the 340,000 gallon washwater recovery tank or to a 360,000 gallon sludge thickener. According to WTP staff, this pump is undersized at 2,000 gpm, but that perception is thought to be caused by the excess flow contribution from the leaking filter valves. Washwater wet well overflows are mitigated by a set of washwater transfer pumps (two pumps, 1,000 gpm each) that send waste to the washwater recovery tank to buffer the equalizing rate.

The washwater recovery tank has a volume of 340,000 gallons. Waste from the recovery tank is pumped to the sludge thickener by three washwater recycle pumps with a firm capacity of 3,000 gpm. The transfer rate is less than the waste flows listed in Table 8.2. Equalization volume in the washwater recovery tank somewhat buffers the need to have that flow rate instantaneously at all times. Theoretically, if washwater could be removed from the tank at the same rate as a filter backwash, then the volume of the tank is not limiting and would function as a "wide spot" in the process. Since the removal of water from that tank is less than the combined waste flow (flow in > flow out), the transfer rate between the two tanks is limiting and eventually the washwater recovery tank will overflow in the times shown in Table 8.3. For this reason, a capital improvement to increase the capacity of the washwater recycle pumps is recommended.

Table 8.3 – Washwater Recovery Tank Time to Overflow

Total Plant Flow (MGD)	160	128	118
Backwash + Solids Flow In (gpm)	5,048	3,943	3,635
Max Flow Out (gpm)	3,000	3,000	3,000
Time to WW Recovery Tank Overflow (hr)	1.8	5.3	11.0

^{1.} Total plant flows represent the demand projections in 2016 at 118 MGD and in 2045 at 128 MGD; the 160 MGD demand condition is the rated treatment capacity of the WTP.

One washwater recycle pump can transfer waste directly to the sludge lagoons through a 16-inch diameter pipe. Currently, this is done frequently to prevent washwater recovery tank overflows, likely due to the leaking valves. This mode of operation places additional loading on the sludge lagoons and is discussed later in this section.

Waste removal from the washwater recovery tank is also limited by downstream processes which include thickener capacity, decant capacity and sludge transfer capacity to the lime lagoons. The capacity of the thickener process depends on multiple factors such as hydraulic loading and treatment goals. The operation of the thickener was recently modified to prevent taste and odor (T&O) compounds from returning into the main treatment process. The capacity at which the thickener operates in a sufficient manner to remove T&O and adequately remove sludge solids is highly dependent on raw water characteristics which change seasonally. In order to determine the limitations of the thickener process, a more-detailed study is required. A capital improvement to replace the thickener is recommended, but can be removed if a study shows that the thickener has adequate capacity.

Decant from the thickener is sent to the aerated water channel at the head of the Central Plant by gravity through a 20-inch diameter pipe. Based on the overflow weir elevation of the thickener, the capacity of this pipe is estimated at approximately 6,000 gpm. Since the pipe capacity is greater than the influent flow (3,365 gpm as shown in Table 8.3), this pipe should be able to prevent the thickener from overflowing; however, City staff have indicated that decant typically operates at approximately 2,000 gpm for unknown reasons. If decant is operating at 2,000 gpm and flow into the thickener is 3,365 gpm, the thickener will overflow. A change in the decant configuration is planned as part of the current East Plant Improvements project to allow decant flow to be sent to both the East and Central Plants; therefore, a capital improvement is not included in this report.

A portion of the flow leaving the thickener can be pumped approximately 5 miles to the lagoon system consisting of three lagoons at a maximum flow rate of 250 gpm. The first lagoon provides equalization and allows solids to settle. Solids and sludge that accumulate are removed by a private contractor on a regular basis. After the first lagoon, decant is conveyed to one of the remaining two lagoons for storage and evaporation. Recent operational changes in sludge plant production have increased the flow entering the lagoons and is overloading the system. The maximum capacity of the lagoon system has not been determined since it is highly dependent on weather patterns, evaporation rates, and groundwater levels.

Due to the overloaded nature of the lagoons, increasing flow to the lagoons is not recommended and a comprehensive study should be conducted to determine the future use of the lagoon system.

8.2.5 Limiting Factor: Filter Loading Limitations

KDHE requires a maximum design hydraulic loading rate of 3 gpm/sf for dual-media filtration; however, higher rates can be accepted by validating filter performance. The City has a variance on this requirement that allows up to 5.7 gpm/sf per filter with all filters in service; therefore, the filtration capacity is equivalent to 11.4 MGD per filter for a total of approximately 160 MGD with all filters in service.

A recent filter evaluation, by Burns and McDonnell, indicated a hydraulic loading rate closer to approximately 4.6 gpm/sf can be achieved without significant improvements to the backwash system; this limits the filter capacity to 128 MGD as listed in Table 8.4. With all filters in service, the WTP can meet the 2016 and 2045 demand projections, but cannot deliver the rated capacity of the WTP. Firm capacity with one filter out of service at a loading of 4.6 gpm/sf is approximately 119 MGD.

Total Plant Flow (MGD)160128118Filter Loading Rate w/ All In Service (gpm/sf)5.74.64.2Filter Loading Rate w/ One Filter Out of Service (gpm/sf)6.14.94.5

Table 8.4 - Filter Loading Rates

These improvements include the previously-mentioned filter cleaning improvements, but cleaning alone will not increase the capacity needed by 2045 with one filter out of service. In order to meet a hydraulic loading rate of 4.9 gpm/sf, replacement of all filter media, underdrains, and backwash rate are required. Capital improvements for the filtration system was recommended in a recent filter evaluation, by Burns and McDonnell, and included in this report; corresponding opinions of probable costs for improvements are summarized at the end of this section. It is important to note, the filter underdrains and media (also indicated in the 2016 Filter Evaluation) require rehabilitation/replacement in the next five years.

As an alternative to performing these filter improvements, building a new filter gallery on the MWTP site was also considered. If a new 80 MGD filter gallery could be constructed and paired with the East Plant, then the East Plant would be a standalone facility. This would provide operational flexibility and would provide additional filtration capacity. Having the additional filtration capacity would be very beneficial if the filter improvements discussed above would not restore the existing filters to full capacity. Since the previously-mentioned filter improvements would restore capacity above the 2045 demand, building a new filter gallery was not evaluated any further.

8.2.6 Chlorine Storage

The City uses chlorine for primary disinfection/CT and adds ammonia to form chloramines prior to distribution. Chlorine disinfection is common practice but comes with some inherent risks. Most facilities use chlorine gas, sodium hypochlorite, or generate disinfectant on-site as their source for chlorine. The use of liquid sodium hypochlorite is considered safer, but is much more expensive than gaseous chlorine. Gaseous chlorine is considered the most cost-effective source of chlorine; however, the storage requirements can be excessive if in large amounts, like Wichita.

The State of Kansas (KDHE) Minimum Design Standards Chapter IX requires the largest storage container must be scrubbed (chemically neutralized) to prevent chlorine gas leakage in the atmosphere. This requires a storage room separated from other facilities, special HVAC systems, scrubber equipment, and leak detection systems, etc. Most facilities using chlorine gas store chemical in either 1-ton containers or 150-lb cylinders. The purpose of relatively small storage containers minimizes the consequences of a leak and reduces scrubbing equipment sizing.

The City stores bulk chlorine in two tanks, each with a capacity of 41,598 lbs. These tanks were installed with the 1992 plant improvements along with a 1-ton chlorine scrubber. Prior to this installation, the facility used 1-ton chlorine cylinders. The tanks are in a building with vented sidewalls that share airspace with ammonia and CO2 bulk storage. The scrubber for the area is designed to scrub the chlorine feed rooms, separated from the bulk storage area. The scrubber also has ductwork to pull chlorine from the bulk storage area; however, since the area is unconfined, its ability to properly scrub the airspace is questionable. This scrubber is not capable of meeting the KDHE minimum design standard for scrubbing the largest container; however, during regular inspections the systems have not been identified as a deficiency by KDHE. Additionally, storage in this amount without an adequate scrubber would not comply with current codes if constructed today. According to the 2015 International Fire Code, table 5003.1.1(2) storage of liquefied gas highly toxics (like chlorine) is limited to 4 pounds, unless an automatic sprinkler system is installed (in which case the allowable quantity is 8 pounds). Since the City is over the exempt amount of 8 lbs, the 2012 International Mechanical Code takes priority. Per the 2012 International Mechanical Code, paragraph 502.9.8.5, it is required to have a scrubber that will scrub the full amount of a release. Since the facility was constructed prior to such codes, it is believed to be grandfathered and therefore, in compliance with codes.

While the current storage system is not in violation of any codes, it still proposes risk and the City should evaluate ways to increase safety. One alternative is replacing bulk chlorine storage with on-site sodium hypochlorite generation. On-Site generation (OSG) is a method of converting salt brine to sodium

hypochlorite using electricity. This generates the chlorine needed for disinfection, and reduces hazardous chemicals storage requirements. This method of generating disinfection chemicals is increasing in demand as utilities invest in the reduction of chlorine gas storage in these amounts. It is recommended that the City perform a more detailed study to further assess potential changes in regulations pertaining to chlorine storage, the feasibility of using OSG at the MWTP, and for a more detailed opinion of probable cost. A capital improvement for OSG is included in this report and is recommended to be completed by year 2020.

Similar safety concerns exist for the anhydrous ammonia storage at the facility. Any future changes to the bulk chemical storage at the facility should address concerns with ammonia as well as chlorine gas. Unlike chlorine, however, there is not a commercially-available method of generating this onsite. The most common method when using ammonia is in a liquid form, such as liquid ammonium sulfate (LAS). An additional study should evaluate the feasibility of converting to liquid ammonia at the MWTP.

8.2.7 Vacuum Priming System: Hess HSPS

Hess HSPS draws suction and water supply from the reservoir system that has a total storage capacity of 35.1 MG from five reservoirs. The total head range in the reservoir system is 15.0 ft, but currently, any pump or pumps must be in service above a water level of 7.0 ft to start. Therefore, the existing vacuum priming system should be replaced to increase effective storage volume in the reservoir system and enhance the operational pumping capability of Hess HSPS. A packaged vacuum priming system to serve all eight pumps is included in the CIP.

8.2.8 Hess Reservoir Recirculation System

The results of the water age analysis discussed in Section 6.8.7 indicated a 22-hour water age in the reservoir system under average day demand condition. The layout of the reservoirs and the pipe network that connects each one limits the ability improve, or lower, water age in the system. The model results also indicate non-uniform water age in each reservoir, with some reservoirs having more turnover than others. Reservoirs with lower water age have more turnover than those with higher water age. Model results indicated the 9.7 MG and 10.6 MG reservoirs have the highest water age and lowest turnover, which is consistent with disinfectant residuals testing completed by City staff. The disinfectant testing indicated very little to zero residual measured in the 9.7 MG and 10.6 MG reservoirs.

Consolidating all storage into a single reservoir is an option to lower water age. However, another solution to recirculate water from the higher water age reservoirs to the lower reservoirs is recommended;

site conditions and constructability to implement a single reservoir of this capacity is limited at this site. A recirculation system will pump water, via submersible sump pumps, from the 9.7 MG and 10.6 MG reservoirs to the 3.0 MG reservoirs to facilitate turnover, mitigate stagnation, and increase disinfectant residuals. Water will be pumped and piped (12-inch diameter, each reservoir) near the influent of 3.0 MG reservoir; no changes to the existing pipe network need to be made). The 3.0 MG reservoir system has the lowest water age and highest turnover of all reservoirs primarily due to its proximity and effluent piping which is near the suction piping of Hess HSPS. The recirculation system, or a portion of the flow, can also be used to supply other WTP service water needs if feasible, to facilitate turnover in these reservoirs. A preliminary pump size, estimated at 500 gpm, in the 9.7 MG and 10.6 MG reservoirs should be reviewed and/or modified depending on the desired turnover, water age and disinfectant residual goals, and/or other plant service water needs that the recirculation system can be customized for.

8.2.9 **East WTP**

The East WTP Improvements project is currently on-going and will provide clarification/softening facilities capable of treating up to 80 MGD of 100 percent groundwater or a blend of surface water and groundwater. This will dramatically improve water treatment flexibility and mitigate the risk of a temporary loss of Cheney water due to a transmission main issue or a severe drought. The existing facilities are not capable of treating 100 percent groundwater and, therefore, require a blend of surface and groundwater supplies for the treatment process. If the Cheney water supply is lost or out of service under the current treatment capability of the WTP, the City has a finite amount of time, based on the water demand, the number of filter cycles needed, and the volume of treated water stored in Hess reservoir system and at Webb Road reservoir, to continue delivering water to customers.

For clarity, filtration capacity will not increase with the East WTP Improvements project, therefore, the overall rated treatment capacity of the WTP will not increase. The rated capacity of the WTP will remain at 160 MGD, and the filtration improvements recommended above still need to be performed to achieve that capacity. Moving forward with the construction phase of the East WTP Improvements project is recommended as it improves capacity, flexibility, and lowers risk under drought conditions with minimal or no surface water supply available. This project also provides more operational flexibility for decant transfer to both the East and Central plants, address the hydraulic bottleneck upstream of the filters if necessary, and more importantly, enable the City to treat 100 percent groundwater which enhances the flexibility of the City's treatment options of their raw water supply sources. Capital costs for these improvements are provided in that project and are not included in this report.

8.2.10 New NWTP

The 2015 Water Resources Plan by the City includes the future potential to supplement the existing WTP with an additional treatment facility located near the intersection of 21st and Zoo Boulevard; this is referred to as the Northwest Treatment Plant (NWTP). A new treatment facility at a location other than the existing WTP provides redundancy and mitigates risk associated with loss of treatment/production, but also carries with it an increased cost of operation to staff, operate, and maintain two WTPs and operational complexities of operating two WTPs during low and moderate demand periods.

The Central Plant is aging and requires major rehabilitation or complete replacement likely in the next 20 years. It is assumed, and likely, that the extent of the Central Plant improvements will not allow uninterrupted treatment service. Therefore, the NWTP is sized for 80 MGD to accommodate necessary Central Plant improvements and provide the level of system-wide treatment redundancy desired by the City in the year 2035. The NWTP trigger is not capacity driven, it's trigger is based on treatment redundancy. An added inherent benefit of the ability to treat and deliver water to the City's customers from multiple locations lessens the severity of any emergency and/or temporary condition that includes loss of treatment. Implementing the NWTP prior to rehabilitation of the Central Plant places its completion within the next 20 years, based on the age of the Central Plant and its condition as confirmed by City staff.

There are several factors impacting the potential processes for the NWTP. The facility will be required to provide softening in addition to all the typical processes. Softening can be completed by lime softening, the current practice, or reverse osmosis. Reverse osmosis (RO) will also remove other constituents like chlorides; however, RO is a high additional cost to construct and operate and disposal of the brine or concentrate must be thoroughly evaluated for feasibility. For the purposes of this report, it is assumed that chloride treatment, when required, will be handled at a different location, likely in the wellfield, and therefore is not included in the NWTP.

Should the City decide to pursue chloride treatment at the NWTP, the following discussion would apply. If chlorides increase in the EBWF to a concentration where their removal is required, an additional treatment technology for the NWTP is required and must be considered in the design as a future provision. RO is one technology that could be used to reduce chloride concentrations in the EBWF groundwater occurs. Other methods for chloride removal include ion exchange and electrodialysis reversal (EDR), but RO is likely the best alternative for the City. Since permitting a disposal mechanism is a fatal flaw for these technologies, developing an acceptable plan for the disposal of the brine for all three alternatives will be a major aspect of future evaluations.

Chlorides have a Secondary Maximum Contaminant Level (SMCL) of 250 mg/L. Additionally, the City has a more stringent finished water quality goal of 80 mg/L chlorides. This is due to existing customers expecting low chloride concentrations in their water, namely dialysis clinics and other industries. The existing treatment process is not capable of removing chlorides. Since RO treatment is primarily for chloride removal, the NWTP is only required to treat raw water that contains chlorides from the EBWF. The remainder of the raw water can be treated with lime softening and conventional filtration. This is a split-stream treatment approach and can deliver lower capital and operating costs, as opposed to treating the entire raw water supply with RO; however, if the surface water supply is lost, then the City would be in a similar treatment capability situation it has been in the past (or pre-East WTP Improvements project).

Under a groundwater only condition for raw water supply, there must be adequate RO capacity to provide 80 MGD of treated water below the SMCL. From a capacity perspective, this condition does not require 80 MGD of RO treatment. Depending on chloride levels, a portion of the raw water flow can bypass the RO process such that the blended water quality is below the SMCL, thereby reducing the RO treatment capacity. Since the amount of water bypassed and blended is dependent on chloride concentration in the raw water source, a detailed evaluation is required to determine the effective capacity for RO treatment. For the purposes of this report, it is assumed that the average chloride concentration in the EBWF is 300 mg/L based on previous studies and as discussed in Section 8.1.4 of this report. Assuming a desired finished water concentration of 80 mg/L and 80% recovery through the RO process, and an overall plant flow rate of 80 MGD, approximately 60 MGD needs to be treated with RO.

Although RO treatment is capable of removing chlorides, this technology has its challenges, primarily with concentrate disposal. A typical RO system can produce approximately 75 to 80 percent permeate and 20 to 25 percent concentrate but these portions are highly variable depending on upstream processes and raw water quality. Current disposal techniques include deep well injection, river outfall, sanitary sewer treatment, and evaporation; it also requires significant infrastructure for disposal, compliance with regulatory drivers, and permitting. These are all significant factors in determining RO treatment viability.

In conclusion, a study is recommended to evaluate the following items in further detail if different treatment capacity and source water end-goals change and/or for capital and operational opinions of probable cost refinement in greater detail beyond that presented herein:

- Evaluate EBWF data on groundwater levels, particularly in the hydraulic barrier area, and the
 resulting changes in chloride concentrations in the wells; conduct additional groundwater
 modeling as necessary;
- Perform a comprehensive review of raw water quality, treatment alternatives and/or eliminate chloride removal options not applicable to the City's raw water constituents;
- Evaluate RO, EDR, and ion exchange alternatives; and
- Select and validate a treatment alternative while considering options for split stream treatment, and concentrate disposal.

8.2.11 Water Treatment Planning and Capital Improvements

Multiple options are evaluated for water treatment planning and capital improvements and are based on triggers for capacity, redundancy, and safety considerations. These three options are detailed below and include the Base Option which addresses near-term and long-term capacity-driven improvements and Option No's. 1 and 2 which address redundancy-driven improvements:

- Base Option the year 2018 and 2020 deadline reflects starting on these improvements due to the high level of need:
 - Washwater Process Improvements: increases the washwater pumping capacity, additional piping, and new 3.0 MGD gravity sludge thickener. The trigger for this improvement is capacity and is recommended for completion by 2018.
 - Opinion of probable cost = \$3.3 million.
 - o Filter Improvements: includes filter media replacement, filter underdrain replacement, backwash chlorination system, piping, valves, instrumentation, controls, and replacement of 48-inch, 36-inch, and 20-inch butterfly valves. These improvements increase filter capacity to 128 MGD with all filters in service. The trigger for this improvement is capacity and is recommended for completion by 2018.
 - Opinion of probable cost = \$8.2 million.
 - New Vacuum Priming System at Hess HSPS: includes skid-mounted vacuum priming system, control, piping, and valves. The trigger for this improvement is replacement and is recommended for completion by 2018.
 - Opinion of probable cost = \$0.32 million.
 - Hess Reservoir Recirculation System: includes submersible pumps situated in the 9.7 MG and 10.6 MG reservoirs and discharge piping to the 4.3 MG reservoir, demolition, electrical, and miscellaneous structural improvements for top slab modifications. The

trigger for this improvement is water quality and is recommended for completion by 2018.

- Opinion of probable cost is \$0.4 million.
- OSG for Disinfection: includes a storage building, hypochlorite generation equipment, storage tanks, instrumentation, controls, electrical, piping, and site work for completion by 2020.
 - Opinion of probable cost is \$15.8 million.

• Option No. 1:

- NWTP: includes raw water storage, supply piping and headworks, clarification and softening, 13.3 MGD of RO, stabilization, filtration, disinfection and other chemical feed, finished water storage and pumping, residuals handling, RO concentrate disposals, and dedicated transmission from the NWTP to Hess Reservoir system. The trigger for this improvement is redundancy and is recommended for completion by 2035.
 - Opinion of probable cost is \$231.2 million.
 - If RO is not required, then \$17.3 million can be deducted from the cost above.
 - If Option 1 is selected, it is in addition to the recommended capital improvements in the Base Option.

• Option No. 2:

- Northwest WTP (NWTP); includes the same items listed for Option No. 1, except the
 dedicated transmission is replaced with additional transmission in the distribution system.
 The trigger for this improvement is redundancy and is recommended for completion by
 2035.
 - Opinion of probable cost is \$186.4 million.
 - If RO is not required, then \$17.3 million can be deducted from the cost above.
 - If Option 2 is selected, it is in addition to the recommended capital improvements in the Base Option.

Recommendations for additional studies include the following:

- Sludge thickener capacity;
- Sludge lagoon capacity and long-term planning recommendations; and
- NWTP alternative treatment options and evaluation of processes to remove chlorides.
- Feasibility of converting to liquid ammonia at the MWTP.

8.3 EXISTING CIPs

As part of this master plan, the City requested projects in their existing CIP be evaluated to determine if they are still needed. The current water treatment facility CIPs are listed below in Table 8.5 and a discussion of the improvements, if they are still needed, and the basis for their need follows.

Table 8.5 - Existing City CIP Listing

	ing City Cit Listing		
CIP	Need Status	Trigger	
Chemical Feed Improvement	Yes	Age	
Treatment Plant Roof Replacement	Yes	Age	
WTP 100% Groundwater	Yes	Redundancy	
WRP Cen Bas & Aeration Rack			
Repair	Yes	Age	
WTP CL2 Scrubber	Yes	Age	
WTP Control Room	Yes	Age	
WTP Filter Rehabilitation	Yes	Age/Capacity	
WTP Filter Valve Repair	Yes	Capacity	
WTP HVAC Safety System	Yes	Age	
WTP Replace East Clarifiers	To be determined by City		
WTP Risk Reduction	To be determined by City		
WTP Roof/Structure Repair	Yes	Age	
WTP Update SCADA to Cur Version	Yes	Age	

Many of these CIPs are age-based and are not directly tied to plant capacity; however, if they were to fail due to age, they will cause capacity problems; therefore, CIPs with triggers for age should take priority over others. Based on discussions with City staff, recommendations for two existing capital improvements related to the filters match those recommended in this master plan. The City should compare these with the information provided in this report to determine the path forward; these improvements are listed below:

- Water Master Plan CIP: Filter Improvements:
 - o Comparable City CIP: WTP Filter Rehabilitation
- Water Master Plan reference: filter valve leaks:
 - Comparable City CIP: WTP Filter Valve Repair, a design-build project was awarded in September 2016 and is included in this report.

8.4 Water Distribution

The hydraulic model is used to determine the need for changes in the pressure zone delineation, size and location of additional pipe and transmission lines, pump stations, and storage for each planning period. Storage is adequate for each planning period based on the maximum day demand projections and

minimum storage requirements for each pressure zone. A detailed storage analysis is included in Section 11.0, Distribution System Master Planning and Analysis.

Pumping improvements are limited and include an additional pump at Southeast BPS and one additional pump at West Maple BPS to meet the 2035 demand projections within their pressure zones. The pressure zone boundary for the East and Northeast zones do not require any changes based on the demand projections and anticipated future growth for the planning periods evaluated in this water master plan; the West Maple pressure zone expands to the north and south for peripheral growth areas (future development beyond the City's water service area) and slightly to the west, absorbing a small area (neighborhood) of the Hess pressure zone in 2035.

The relationship of options evaluated in the Water Treatment Facilities Evaluation (in this section) with the distribution system improvements is summarized below:

• Base Option:

- 2017 planning period includes approximately 350 LF of 24-inch water mains required for system hydraulics;
- 2020 planning period includes approximately 7.2 miles of 8-, 12-, 16-, 24-, and 30-inch water mains required for system hydraulics and fire flow;
- 2035 planning period includes approximately 1.2 miles of 8-, 12-, 16-, 20-, and 24-inch water mains required for system hydraulics;
- 2045 planning period includes approximately 79.6 miles of 8- and 12-inch water mains required to support future growth areas; and
- Total opinion of probable cost for all planning periods is estimated at \$45.1 million through year 2045.

• Option No. 1:

There are no additional distribution system improvements needed to support Option No. 1 which includes the new NWTP and dedicated transmission to Hess Reservoir system; Hess HSPS continues to serve as the primary pumping facility for the entire distribution system. If Option No. 1 is selected, the distribution system improvements identified in the Base Option still apply.

• Option No. 2:

This option evaluates the new NWTP with direct service to the distribution system and requires approximately three miles of a 66-inch transmission main within the distribution system. This transmission main parallels the existing 36-inch transmission main from 21st and Zoo Boulevard to W Central Avenue and N McLean Boulevard where it should

tie into the existing 48-inch transmission main. For clarity, if Option No. 2 is selected, this improvement is required in addition to those identified in the Base Option.

Opinion of probable cost is \$25.7 million.

Recommendations for additional studies include the following:

- Replace centralized storage in Hess Reservoir system with elevated storage in the distribution system to determine impacts on pressure zone delineation, distribution system hydraulics, changes in system operation, and support emergency storage goals desired by the City.
- Evaluate system hydraulics with expansion of the East pressure zone to determine if additional
 demand provides extended use of the Southeast BPS under demand conditions other than the
 maximum day and peak hour on the maximum day and determine impact of corresponding
 hydraulics and pressure control at Central and Main caused by Hess pressure zone contraction.
- Pump testing at 37th Street BPS to establish pump curves and summarize system conditions requiring its use to better define its long-term future with the integration of the Northeast Tower and new pumps at Webb Road PS serving the Northeast pressure zone. As indicated in Section 6.1.3, no conclusions can be drawn on the 37th Street BPS pumping capacity because SCADA historian data suggests the pump curves have shifted or are being influenced by the mechanical governor on Pump No. 1.

* * * * *

9.0 REGULATORY REVIEW

9.1 General

This section of the report provides a summary of the current and anticipated future State and Federal drinking water quality regulations and their potential impact on the City of Wichita. The Main WTP currently treats a blend of surface water from Cheney Reservoir and groundwater from the Equus Beds Well Field (EBWF), Bentley Reserve Well Field, and Local Well Field. A WTP with surface water and groundwater must produce water that meets State and Federal mandated regulations for surface water.

In general, States are primarily concerned with the administration of Federal drinking water requirements, but on some topics, they may add additional or stricter requirements. The National Primary Drinking Water Standards adopted by Kansas are referenced by Kansas Administrative Regulation (KAR) designations. The requirements consist of maximum contaminant levels (MCLs) and treatment techniques. The requirements and analytical methods for measuring the MCLs are summarized in KAR 28-15 and KAR 28-15a. The primary State and Federal requirements that guide drinking water treatment in Kansas are summarized in this document.

9.1.1 Regulatory Background

The regulatory evaluation includes a review of current and anticipated water quality regulations that may impact the City of Wichita. This review takes into consideration the following current and anticipated drinking water regulations:

- Safe Drinking Water Act (SDWA) and its amendments:
 - National Primary Drinking Water Regulations (NPDWRs)
 - Microorganisms
 - Disinfection Byproducts
 - Organic Contaminants
 - Inorganic Chemicals
 - Radionuclides
 - Disinfectants
 - National Secondary Drinking Water Regulations (NSDWRs)
 - o Arsenic Rule
 - o Lead and Copper Rule
 - Radionuclide Rule
 - o Radon Rule

- Filter Backwash Recycling Rule
- Surface Water Treatment Rule (SWTR)
- Total Coliform Rule (TCR)
- Microbial/Disinfection Byproduct Rules
 - o Interim Enhanced Surface Water Treatment Rule (IESWTR)
 - o Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)
 - Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)
 - Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 D/DBPR)
 - o Stage 2 Disinfectants/Disinfection Byproducts Rule (Stage 2 D/DBPR).
- Unregulated Contaminant Monitoring (UCM) for large and small utilities

9.2 Existing Water Quality Regulations

9.2.1 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) of 1974 established primary drinking water regulations to ensure the distribution of safe drinking water. These regulations were the first to be implemented to public water supplies (PWSs) in the United States (US), covering both chemical and microbial contaminants. They remained in place for more than 10 years with minor revisions, including a revised fluoride standard, addition of a total trihalomethanes standard, and interim regulations for radionuclides in potable water.

The SDWA authorized the United States Environmental Protection Agency (USEPA) to promulgate regulations regarding water supply. In 1986, Congress passed widespread amendments to the SDWA, which significantly altered the rate at which the USEPA was to set drinking water standards. These amendments resulted in a three-fold increase in the number of contaminants regulated. The National Interim and revised Primary Drinking Water Regulations promulgated prior to 1986 were redefined as National Primary Drinking Water Regulations.

The 1996 amendments to the SDWA greatly enhanced the existing law by recognizing source water protection, operator training, funding for water system improvements, and public information as important components of safe drinking water. Among others, the 1996 amendments required the USEPA to develop rules to balance risks between microbial pathogens and disinfection byproducts (DBP), named the Microbial/Disinfection Byproduct (M/DBP) Rules. Several rules emerged from this requirement, including the Interim Enhanced Surface Water Treatment Rule (IESWTR), the Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules (Stage 1 D/DBPR and Stage 2 D/DBPR), and the Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules (LT1ESWTR and LT2ESWTR).

Since the passage of the 1996 amendments, numerous regulations specific to surface water and groundwater sources have been finalized by the USEPA including: Total Coliform Rule, Lead and Copper Rule, Radionuclide, Arsenic, and additional standards for various organic and inorganic chemicals. The EPA is currently engaged in a process for proposing and promulgating additional rules associated with these amendments.

9.2.2 Primary and Secondary Drinking Water Regulations

The National Primary Drinking Water Regulations (NPDWRs) of the SDWA legislated by Congress and adopted by the State of Kansas, are currently set for 83 contaminants, including turbidity, six indicator microorganisms, four radionuclides, 16 inorganic contaminants, and 57 organic contaminants. MCLs and maximum contaminant level goals (MCLGs) have been set for 73 contaminants and three disinfectants. Ten other contaminants have treatment technique (TT) requirements. The Federal and State MCLs for the contaminants listed in the NPDWR are summarized in Table G.1 of Appendix G.

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply; however, states may choose to adopt them as enforceable standards.

Federal and State secondary standards are recommended for 15 contaminants that may cause cosmetic effects or impact aesthetic quality (i.e. taste, color, and odor) of drinking water. The Secondary Drinking Water Standards are summarized in Table G.2 of Appendix G. Although the secondary regulations are non-enforceable guidelines, Kansas has a public notification requirement for fluoride.

9.2.2.1 Inorganic Compounds

Inorganic compounds (IOC) consist of substances that do not have organic carbon in their composition. The K.A.R. 28-15a-62 set maximum contaminant levels (MCLs) for eight metals and two non-metal contaminants, as listed in Table 9.1. Most of these IOCs occur naturally in the environment and are soluble in water. Because of this, they are potential contaminants of drinking water. Not all IOCs originate from natural mineral deposits; industrial activities such as metal finishing, textile manufacturing, mining operations, electroplating, and manufacturing of fertilizers, paints, and glass also generate these contaminants.

Table 9.1 - Inorganic Compounds

Compound Name	MCL		Reported	l Concentrati	on (μg/L)	
Compound Name	(mg/L)	2010	2011	2012	2013	2014
Antimony	6					
Arsenic	10	1.5	2.1	2	1.6	1.3
Barium	2000	30	44	52	42	74
Beryllium	4					
Cadmium	5					
Chromium	100		1.1			
Cyanide	200					
Fluoride	4000					
Mercury	2					
Nickel	100					
Selenium	50	5	3.2	3.8	3.5	1.9
Thallium	2					

Notes:

1. 1. Data from 2010 to 2014.

These IOC contaminants are toxic to humans at various levels. Cadmium, chromium, and selenium can cause damage to the kidneys, liver, and nervous and circulatory systems while barium has been associated with high blood pressure, and mercury has been shown to damage kidneys. Antimony, beryllium, cyanide, nickel, and thallium have been shown to damage the brain, lungs, kidneys, heart, spleen and liver. This class of drinking water contaminants can be removed from drinking water using various available technologies such as coagulation/filtration, lime softening, reverse osmosis, ion exchange, chlorine oxidation, activated alumina, and granular activated carbon.

Data collected between 2010 and 2014 showed non-detect for most inorganic samples. Arsenic, barium, chromium, and selenium were measured at low levels on raw, finished, and distribution system samples. The values detected in the distribution system were well below the MCL for each contaminant. For example, barium was detected at 0.17 mg/L on Cheney, 0.10 mg/L on EBWF, and distribution samples ranged between 0.04 and 0.07 mg/L in 2014, well below the MCL of 2 mg/L.

9.2.2.2 Volatile Organic Compounds

Volatile organic compounds (VOCs) are commonly referred to as organic solvents. These compounds are generally found as constituents of many degreasers, industrial cleaners, spot/stain removers, paint thinners, in some paints, varnishes and lacquers, in many paint removers/strippers, in many pesticides/herbicides, in most dry-cleaning chemicals, in many printing inks and printing press chemicals, in most petroleum products including many types of fuels. These compounds can often be identified by

their distinct aromatic smell. Most of these compounds are flammable and toxic to varying degrees; therefore, they are also a potential source of environmental pollution and pose a health hazard. The 21 volatile organic compounds regulated by K.A.R. 28-15a-61 are shown below in Table 9.2. Data collected between 2010 and 2014 for the Wichita WTP showed non-detect for each VOC sample.

Table 9.2 - Volatile Organic Compounds¹

Compound Name	MCL (mg/L unless noted)	Uses
Benzene	0.005	fuels, pesticides, paints, pharmaceutical
Carbon tetrachloride	0.005	degreasing agents, fumigants
p-Dichlorobenzene	0.075	insecticides, moth balls
o-Dichlorobenzene	0.6	insecticides, industrial solvents
1,2 Dichloroethane	0.005	gasoline, insecticides
1,1 Dichloroethylene	0.007	paints, dyes, plastics
cis-1,2 Dichloroethylene	0.07	industrial solvents, chemical manufacturing
trans-1,2 Dichloroethylene	0.1	industrial solvents, chemical manufacturing
Dichloromethane	0.005	paint strippers, refrigerants, fumigants
1,2 Dichloropropane	0.005	soil fumigants, industrial solvents
Ethylbenzene	0.7	gasoline, insecticides
Monochlorobenzene	0.1	industrial solvents, pesticides
Styrene	0.1	plastics, synthetic rubber, resins
Tetrachloroethylene	0.005	dry cleaning/industrial solvents
Toluene	1	gasoline, industrial solvents
1,2,4 Trichlorobenzene	0.07	industrial solvents
1,1,1 Trichloroethane	0.2	metal cleaning/degreasing agent
1,1,2 Trichloroethane	0.005	industrial degreasing solvents
Trichloroethylene	0.005	paint strippers, dry cleaning, degreasers
Vinyl chloride	0.002	plastics/synthetic rubber, solvents
Xylenes	10	paints/inks solvent, synthetic fibers, dyes

Notes:

9.2.3 Synthetic Organic Compounds

Synthetic organic compounds (SOCs) are man-made compounds, many of which are chlorinated and used as herbicides, pesticides, fungicides, and insecticides. There are 33 synthetic organic compounds that are regulated in K.A.R. 28-15a-61 and summarized below in Table 9.3. Systems failing to monitor or having a MCL violation must notify the public of such violation and provide proof of performing the public notice to KDHE. Data collected between 2010 and 2014 for the Wichita WTP showed non-detect for each SOC sample.

^{1.} Data collected between 2010 and 2014 for the Wichita WTP showed non-detect for each VOC sample.

Table 9.3 - Synthetic Organic Compounds¹

Alachlor (Lasso) Alachlor (Lasso) Aldicarb Sulfone Aldicarb Sulfon	Table 5	Table 9.3 - Synthetic Organic Compounds ¹					
Aldicarb usifoxide 0.003 insecticide Aldicarb sulfoxide 0.003 insecticide Aldicarb sulfone 0.003 insecticide Aldicarb sulfone 0.003 insecticide Aldicarb sulfone 0.003 insecticide Aldicarb sulfone 0.0003 weed control Benzo(a)pyrene 0.0002 coal tar lining & sealants Carbofuran (Furadan 4F) 0.04 rootworm, weevil control Carbofuran (Furadan 4F) 0.004 rootworm, weevil control Carbofuran (Furadan 4F) 0.002 termite control Dilapon 0.2 herbicide Dibromochloropropane(DBCP, Nemafume) pesticide, nematocide, soil fumigant 2,4-D (2,4-dichlorophenoxyacetic acid) 0.07 weed control, defoliant 2,4-5-TP (Silvex) 0.05 herbicide, defoliant Di(diethylhexyl)adipate 0.4 plasticizer Di(diethylhexyl)adipate 0.4 plasticizer Di(diethylhexyl)phthalate 0.006 plasticizer Dinoseb (2,4-dinitro-6-sec-butylphenol) 0.007 insecticide, herbicide Endothall 0.1 herbicide, defoliant Endrin 0.002 herbicide Endothall 0.1 herbicide defoliant Endrin 0.002 insecticide Endothall 0.1 herbicide Heylene Dibromide (EDB, Bromofume) 0.0005 gasoline additive, fumigants, & solvents Glyphosate 0.7 herbicide Heptachlor (H-34, Heptox) 0.0004 termite control Heptachlor epoxide 0.0002 insecticide Hexachlorobenzene 0.001 byproduct of solvents & pesticides Hexachlorocyclopentadiene 0.05 pesticide Hexachlorocyclopentadiene 0.05 pesticide Methoxychlor (DMDT, Marlate) 0.04 insecticide Methoxychlor (DMDT, Marlate) 0.001 herbicide, fungicide, wood preservative Picloram (Tordon) 0.5 herbicide, defoliant Polychlorinated Biphenyls (PCB, Aroclors) 0.0005 herbicide Simazine 0.0004 herbicide	Compound Name	MCL (mg/L unless noted)	Uses				
Aldicarb sulfoxide Aldicarb sulfone Aldicarb sulfone Aldicarb sulfone Aldicarb sulfone Aldicarb sulfone Altrazine (Atranex, Crisazina) Benzo(a)pyrene Dispersive the sulface of the sulfac	Alachlor (Lasso)	0.002	pesticide				
Aldicarb sulfone Atrazine (Atranex, Crisazina) Dispersione Atrazine (Atranex, Crisazina) Dispersione Atrazine (Atranex, Crisazina) Dispersione Dispersione Dibromochloropropane(DBCP, Nemafune) Dispersione Disper	Aldicarb	0.003	insecticide				
Atrazine (Atranex, Crisazina) Benzo(a)pyrene 0.0002 coal tar lining & sealants Carbofuran (Furadan 4F) 0.04 rootworm, weevil control termite control Dalapon 0.2 Dibromochloropropane(DBCP, Nemafume) 2,4-D (2,4-dichlorophenoxyacetic acid) Di(diethylhexyl)adipate Di(diethylhexyl)phthalate Di(diethylhexyl)phthalate Diouguat Endothall Endrin Endrin Chlorabe Dibromide (EDB, Bromofume) Diyphosate Heptachlor (H-34,Heptox) Heptachlor (H-34,Heptox) Heptachlor epoxide Hexachlorocyclopentadiene Lindane Dival (Vydate) Pentachlor (PCP) Picloram (Tordon) Polychlorinated Biphenyls (PCB, Arcolors) Simazine Jones (1000) Lermite control deed control rootworm, weevil control deed control rootworm, weevil control, defoliant Didut Didut Didut Didut Didut Didut Diabeticizer Dinoseb (2,4-dinitro-6-sec-butylphenol) Diouo Diabeticizer Dinoseb (2,4-dinitro-6-sec-butylphenol) Diouo Diabeticizer Dinoseb (2,4-dinitro-6-sec-butylphenol) Diouo Diabeticizer Dinoseb (2,4-dinitro-6-sec-butylphenol) Diouo Diabeticizer Dinoseb (2,4-dinitro-6-sec-butylphenol) Diouoo Diabeticizer Directicide Diabeticize Dinoseb (2,4-dinitro-6-sec-butylphenol) Diouoo Diabeticize Diabetic	Aldicarb sulfoxide	0.003	insecticide				
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Simazine 0.004 herbicide 2,3,7,8 TCDD (Dioxin) 3.00E-08 pesticide byproduct	Picloram (Tordon)	0.5	herbicide, defoliant				
2,3,7,8 TCDD (Dioxin) 3.00E-08 pesticide byproduct	Polychlorinated Biphenyls (PCB, Aroclors)	0.0005	herbicide				
	Simazine	0.004	herbicide				
Toxaphene 0.003 pesticide	2,3,7,8 TCDD (Dioxin)	3.00E-08	pesticide byproduct				
1	Toxaphene	0.003	pesticide				

Notes:

1. Data collected between 2010 and 2014 for the Wichita WTP showed non-detect for each SOC sample.

Compliance Status

Based on the review of Wichita WTP lab data, none of the aforementioned compounds have exceeded the maximum contaminant levels (MCLs). Most IOCs, VOCs, and SOCs measured are below the analytical detection limit and all are below the MCL.

9.2.3.1 Arsenic Rule

On January 22, 2001, the EPA proposed a reduction in the arsenic standard from 50 μ g/L to 10 μ g/L. Due to delays in the announcement of the proposed rule, the final rule was published on February 22, 2002 with a compliance date for all drinking water systems by January 23, 2006.

Compliance Status

Raw water arsenic concentrations from Cheney and EBWF raw water samples between 2010 and 2015 were found to be below the maximum contaminant level of $10 \,\mu\text{g/L}$. In 2014, Cheney and EBWF respectively measured 3.67 and 2.71 $\,\mu\text{g/L}$ and the distribution samples ranged between 1.47 and 1.57 $\,\mu\text{g/L}$. Data collected in 2015 showed slightly lower arsenic concentrations. While arsenic can be difficult to remove, some arsenic will be removed by co-precipitation mechanisms with the iron-hydroxide floc particles that form during flocculation. Additional removal can be achieved with a higher coagulant dose if the arsenic oxidation state is +5. Arsenic that exists in the +3 oxidation state will need to be oxidized to +5 before it will be removed from flocculation or filtration.

9.2.3.2 Lead and Copper Rule

The Lead and Copper rule requires PWS serving greater than 10,000 people to sample household taps for lead and copper and conduct distribution system sampling for certain water quality parameters (pH, alkalinity, calcium, etc.). Lead and copper samples must be collected from 100 "worst case" home sites (Tier 1) and water quality parameters must be collected from 25 sites in the distribution system.

On January 12, 2000, the USEPA republished the Lead and Copper Rule with minor changes, also known as the Lead and Copper Rule Minor Revisions (LCRMR). The LCRMR does not change the action levels for lead or copper, nor does it affect the rule's basic requirements. The modified rule addresses the following broad categories:

- Demonstration of optimal corrosion control
- Lead service line replacement requirements
- Public education requirements
- Monitoring requirements

- Analytical methods
- Reporting and record-keeping requirements

• Special primacy considerations

On October 10, 2007, USEPA published additional revisions and clarifications. These revisions were intended to enhance the implementation of the LCR in the areas of monitoring, treatment, customer awareness, lead service line replacement, and improving public education. The four new requirements are as follows:

Water systems are required to provide advanced notification and gain the approval of the primacy
agency for intended changes in treatment or source water that could increase corrosion of lead.
 The State must approve the planned changes using a process that will allow regulators and water
systems to take as much time as needed to consult about potential problems.

 All utilities must now provide a notification of tap water monitoring results for lead to owners and/or occupants of homes and buildings who consume water from the taps that are part of the utility's sampling program.

• Utilities are required to reconsider previously "tested-out" lines when resuming lead service line replacement programs. This provision applies to systems that had: (1) initiated a lead service line replacement program; (2) complied with the lead action level for two consecutive monitoring periods and discontinued the lead service line replacement program; and (3) subsequently were re-triggered into lead service line replacement.

• The content, distribution methods, and timeframe of the public education materials that must be disseminated after a lead action level exceedance have been changed.

The USEPA has established the following action levels for lead and copper for the 90th percentile of home tap samples:

• Lead: 0.015 mg/L

Copper: 1.3 mg/L

If the lead and copper concentrations in the 90th percentile of home tap samples are greater than these values, the utility must conduct a public education program.

The goal of the lead and copper regulation is for utilities to optimize their corrosion control treatment. Under this regulation, there are two ways in which a utility is considered to have "optimized" their corrosion control:

• If it can be demonstrated to the regulatory agency that the utility has performed corrosion control steps "equivalent" to those required by USEPA.

• If the difference between the highest level of lead in the source water and the 90th percentile tap samples are less than the practical quantitation level (PQL) for lead (0.05 mg/L).

Compliance Status

According to the City of Wichita's Consumer Confidence Reports and the Lead and Copper Rule Monitoring Reports issued to KDHE, the distribution system testing conducted in 2010 and 2012 indicate compliance with the provisions of the Lead and Copper Rule based upon the 90th percentile of home tap samples.

In 2010, 51 tap samples were collected and analyzed for lead and copper and the 90th percentile for lead and copper was 0.007 and 0.086 mg/L, respectively. In 2012, 50 samples were collected and analyzed for lead and copper and the 90th percentile for lead and copper was 0.008 and 0.096 mg/L, respectively.

9.2.4 Radionuclides Rule

On December 7, 2000, the EPA announced updated standards for radionuclides and a new standard for uranium, as required in the 1986 amendments to the SDWA. The revised standards are as follows:

• Combined Radium 226/228: 5 pCi/L

• Total Beta Emitters: 4 mrem/yr

Gross Alpha MCL: 15 pCi/L *

• Uranium MCL: 30 µg/L

* Excludes uranium and radon but includes Ra-226.

This rule became effective December 8, 2003. The monitoring requirements were phased between December 2000 and December 2003. Water systems will determine initial compliance under the new monitoring requirements using the average of four quarterly samples, or at state-direction, using appropriate grandfathered data. Kansas WTPs are required to meet the MCLs for radionuclides per KAR 28-15a-66 based on SDWA regulations.

Compliance Status

According to the City of Wichita's Consumer Confidence Reports and data collected between 2010 and 2014, each radionuclide was below detection and in compliance with the Radionuclides Rule.

Radionuclide	Wichita WTP
Combined Radium	Below Detection
Total Beta Emitter	Below Detection
Gross Alpha	Below Detection
Uranium	Below Detection

9.2.4.1 Radon Rule

Radon is a naturally occurring radioactive gas found in the subsurface. Breathing radon in the indoor air of homes is the primary public health risk from radon, contributing to about 20,000 lung cancer deaths each year in the United States, according to a 1999 report by the National Academy of Sciences (NAS) on radon in indoor air. Based on a second NAS report on radon in drinking water, EPA estimates that radon in drinking water causes about 168 cancer deaths per year.

The 1996 Safe Drinking Water Act Amendments required EPA to establish several new, health-based drinking water regulations, including a multimedia approach to address the public health risks from radon. The proposed Radon Rule was published on November 2, 1999. The regulation provides two options for the maximum level of radon that is allowable in community water supplies. The proposed MCL is 300 pCi/L and the proposed alternative MCL is 4,000 pCi/L. The drinking water standard that would apply for a system depends on whether a state or community water system (CWS) develops a multi-media mitigation program. The lower alternative standard could be used in conjunction with an EPA approved program to reduce indoor air radon levels. Kansas WTPs are required to meet the MCLs for radionuclides per KAR 28-15a-66 based on SDWA regulations.

Compliance Status

According to the City of Wichita's Consumer Confidence Reports and data collected between 2010 and 2014, radon was detected at low concentrations, well below the 300 pCi/L. Therefore, the Wichita WTP is in compliance with the Radon Rule.

9.2.4.2 Filter Backwash Recycling Rule

In May 2001, EPA released a rule governing the process of recycling waste water generated by the backwashing of drinking water filters. The Filter Backwash Recycling Rule (FBRR) is required by the Safe Drinking Water Act as one method of reducing the risks posed to consumers by microbial contaminants that may be present in public drinking water supplies.

The purpose of this rule is to minimize Cryptosporidium concentrations in the treated water due to the recycling of sludge supernatant and filter backwash wastewater to the head of the treatment plant. The major requirements of this rule are as follows:

- Systems that recycle backwash waste must do so prior to the point of application of primary coagulant.
- Direct Filtration plants could be required to provide detailed recycle treatment information to the State (which could then require modifications).
- Conventional treatment plants that practice direct recycle, employ 20 or fewer filters to meet production requirements during a selected month, and recycle spent filter backwash water, thickener supernatant, and/or liquids from dewatering processes within the treatment process must perform a one month, one-time recycle self-assessment. The self-assessment requires hydraulic flow monitoring and that certain data be reported to the State, which may require that modifications be made to the recycling practices to protect public health.

Compliance Status

The Wichita WTP is currently in compliance with this rule.

9.2.5 Surface Water Treatment Rule (SWTR)

On June 29, 1989, the USEPA promulgated the SWTR, which became effective on December 31, 1990. Systems using surface water or ground water under direct influence (GWUDI) as a potable water source must provide treatment to reduce turbidity, *Giardia, Legionella*, viruses, and heterotrophic plate count (HPC) bacteria. Specifically, the SWTR establishes *treatment* and performance standards to provide a minimum reduction of 99.9 percent (3-log) for Giardia cysts, and 99.99 percent (4-log) reduction for viruses. The overall reduction of *Giardia* and viruses is to be achieved by multiple treatment barriers involving a combination of physical removal by pretreatment and filtration, and inactivation by disinfection.

The federal SWTR stipulates several specific requirements for turbidity and disinfection for filtration plants. For conventional filtration, the turbidity requirements are as follows:

• The turbidity of representative samples of a system's filtered water must be less than or equal to 0.5 Nephelometric Turbidity Units (NTU) in at least 95 percent of the measurements taken each month.

 The turbidity level of representative samples of a system's filtered water must at no time exceed 5 NTU.

Well-operated conventional treatment plants, which meet or exceed (attain values lower than) the 0.5 NTU effluent turbidity standard, are credited with a 2.5-log removal of Giardia cysts and a 2-log removal of viruses. Given this, the disinfection treatment must be sufficient to ensure the following:

- The disinfection process achieves at least 0.5-log inactivation of Giardia cysts and at least a 2-log inactivation of viruses.
- Compliance with the disinfection requirement must be demonstrated by meeting minimum "CT" requirements, where "C" is the residual disinfectant concentration in mg/L, and "T" is the effective contact time in minutes with the disinfectant.
- The residual disinfectant concentration in the water entering the distribution system cannot be less than 0.2 mg/L of free chlorine or 0.5 mg/L of chloramine for more than four hours.
- The residual disinfectant concentration in the distribution system cannot be undetectable in more than 5 percent of the samples taken each month for any two consecutive months. Water in the distribution system with an HPC concentration less than or equal to 500 colony forming units (cfu)/mL is deemed to have a detectable disinfectant residual for purposes of determining compliance with this requirement.

Compliance Status

The Wichita WTP is classified as a well-operated conventional WTP by meeting turbidity requirements less than 0.5 NTU and is credited with 2.5-log Giardia and 2-log of virus disinfection credit. Chlorine is added to meet 0.5-log Giardia and 2-log viruses. As a result, the Wichita WTP is currently in compliance with this rule.

9.2.5.1 Disinfection

Disinfection is achieved by contact with free chlorine after filtration in the chlorine contact basin. The chlorine dose varies based on demand and can be as high as 5 mg/L. Ammonia is applied at the end of the chlorine contact basin to create monochloramine for use as a secondary disinfectant with a free ammonia goal less than 0.1 mg/L.

The necessary "CT" values to achieve 0.5-log inactivation of Giardia Lamblia and 2.0 log inactivation of viruses for various alternative disinfectants are summarized in Tables 9.4 and 9.5. These tables indicate that when using free chlorine as the primary disinfectant, the inactivation of Giardia is the controlling CT

value. Temperature data collected from 2013-2015 is summarized in Appendix H, with values ranging between 5 and 28°C.

Table 9.4 - CT Values (mg/L-min) to Achieve 0.5 Log Giardia Lamblia Inactivation

Disinfectant		Temperature			
Disinfectant	pН	5°C	10°C	15°C	20°C
Free Chlorine (2)	6	20	15	10	8
	7	29	22	15	11
	7.5	36	27	18	13
	8	43	32	22	16
	9	63	47	31	24
Ozone	6-9	0.32	0.23	0.16	0.12
Chlorine Dioxide	6-9	4.3	4	3.2	2.5
Chloramines (preformed)	6-9	365	310	250	185

Notes:

- 1. Adapted from EPA Guidance Manual.
- 2. CT values will vary depending on free chlorine concentration. Indicated CT values are for 2.6 mg/L free chlorine.

Table 9.5 - CT Values (mg/L-min) to Achieve Virus Inactivation

		Temperature				
Disinfectant	Log Inactivation	Wi	Winter		Summer	
		5°C	10°C	15°C	20°C	
Free Chlorine (2)	2.0	4	3	2	1	
	3.0	6	4	3	2	
	4.0	8	6	4	3	
Ozone	2.0	0.6	0.5	0.3	0.25	
	3.0	0.9	0.8	0.5	0.4	
	4.0	1.2	1	0.6	0.5	
Chlorine Dioxide	2.0	5.6	4.2	2.8	2.1	
	3.0	17.1	12.8	8.6	6.4	
	4.0	33.4	25.1	16.7	12.5	
Chloramines (preformed)	2.0	857	643	428	321	
	3.0	1423	1067	712	534	
	4.0	1988	1491	994	746	

Notes:

- 1. Adapted from EPA Guidance Manual.
- 2. CT values will vary depending on free chlorine concentration. Indicated CT values are for 2.6 mg/L free chlorine.

Compliance Status

The Wichita WTP is able to achieve the required CT credit for 0.5-log Giardia and 2-log viruses with free chlorine using a chlorine contact basin. Monochloramine is formed after CT credit to maintain a residual in the distribution system. As a result, the Wichita WTP is in compliance with Federal and State disinfection regulations.

9.2.6 Total Coliform Rule

On June 29, 1989, EPA promulgated a revised regulation for total coliforms. Where the previous regulation was based on the density of coliforms in a given volume of water, the revised rule is based on the presence/absence of coliforms. Under the TCR, utilities must develop a monitoring plan to collect samples representative of water throughout the distribution system.

For systems that collect 40 or more samples per month, the rule allows no more than 5 percent positive samples per month. If a system has greater than 5 percent total coliform-positive (TC-positive) samples in a month, then this is considered a monthly MCL violation, which needs to be reported to the KDHE and to the public in a specific timeframe. All TC-positive samples must be analyzed for the presence of Escherichia coli (E. coli) or fecal coliforms. If two consecutive samples are TC-positive and one is also fecal coliform- or E. coli-positive, then this is defined as an acute violation of the MCL; the system must collect repeat samples and notify the KDHE and the public using mandatory language developed by the USEPA.

Secondary disinfection is required under the TCR in accordance with the following:

- A minimum disinfectant residual of 0.2 mg/L free chlorine or 0.5 mg/L chloramines measured as total chlorine must be present throughout the distribution system continually.
- A sample with HPCs less than 500 cfu/100 mL is assumed to carry the required minimum residual.

Compliance Status

Microbial data collected between 2010 and 2014 were absent of E.coli. Total coliforms ranged between 1.08 percent (October 2010) and 3.03 percent (August 2012) of all samples collected. The monochloramine residual was higher than 2 mg/L for all distribution sites. As a result, the Wichita WTP is currently in compliance with each of the requirements listed in this section.

9.2.7 Microbial/Disinfection Byproducts Rule

Disinfection of drinking water is one of the major public health advances of the 20th century; however, the disinfectants themselves can react with naturally occurring materials in the water to form unintended byproducts that may pose health risks. A major challenge for water suppliers is balancing the risks from microbial pathogens and disinfection byproducts. The following set of five SDWA amendments together address these risks.

9.2.7.1 Interim Enhanced Surface Water Treatment Rule

Following promulgation of the SWTR in 1989, several waterborne outbreaks of Cryptosporidiosis occurred in the U.S. In response, the SDWA required the USEPA to promulgate an enhanced SWTR by November 1998 to address the risk of chlorine resistant pathogens such as Cryptosporidium. However, the rule was to have been based upon information obtained from the Information Collection Rule (ICR) that would not be available until mid-1999.

To address these concerns and comply with the 1998 congressional mandate, the USEPA expedited the development and promulgation of the IESWTR for large systems. The primary purposes of the IESWTR are:

- To improve control of microbial pathogens in drinking water, in particular, Cryptosporidium.
- To guard against significant increases in microbial risk that might otherwise occur when systems implement Stage 1 of the Disinfectants/Disinfection Byproducts Rule (Stage 1 D/DBPR).

The IESWTR was final on December 16, 1998 and became effective in December 2001. The Rule built upon the treatment technique requirements of the SWTR with the following provisions:

- A MCLG of zero for the protozoan genus Cryptosporidium.
- Filtered surface water and GWUDI systems, which serve 10,000 or more people, must achieve at least 99 percent (2-log) removal of Cryptosporidium.
- The IESWTR strengthened turbidity performance requirements as measured every 4 hours in the combined filter effluent which include:
 - Average turbidity of < 0.3 NTU in 95 percent of the samples.
 - o Maximum allowable turbidity of 1.0 NTU.
- Monitoring of individual filter effluents for process control is required every 15 minutes, with the exception that reporting to the State may be required based on the following criteria:

 Any individual filter with an effluent turbidity >1.0 NTU based upon two consecutive measurements taken 15 minutes apart.

- Any individual filter with an effluent turbidity > 0.5 NTU after 4 hours of ripening based on two measurements taken 15 minutes apart.
- Self-assessment in conformance with the USEPA published guidelines is required for any filter with an effluent turbidity > 1.0 NTU, based upon two measurements taken 15 minutes apart at any time in each of three consecutive months.
- Comprehensive Performance Evaluation (CPE) in conformance with the USEPA
 published guidelines is required for any filter with an effluent turbidity > 2.0 NTU, based
 upon two measurements taken 15 minutes apart at any time in each of two consecutive
 months.
- Surface water and GWUDI systems are required to cover all new treated water reservoirs, holding tanks, and other storage facilities.

Compliance Status

Average turbidity is less than 0.3 NTU in more than 95 percent of the samples. The Wichita WTP is in Cryptosporidium Bin 1 category, so no additional treatment credit is required. As a result, the Wichita WTP is currently in compliance with this rule.

9.2.7.2 Long Term 1 Enhanced Surface Water Treatment Rule

The Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) was proposed on April 10, 2000 and promulgated on January 14, 2002. The purpose of the LT1ESWTR was to improve control of microbial pathogens in drinking water and address risk trade-offs with disinfection byproducts. This rule also extended the requirements of the IESWTR to systems serving less than 10,000 people.

Quick Reference Guides to LT1ESWTR Rule can be found on the EPA website: http://water.epa.gov/lawsregs/rulesregs/sdwa/mdbp/lt1/lt1eswtr.cfm

9.2.7.3 Long Term 2 Enhanced Surface Water Treatment Rule

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) was promulgated in December 2005 and published in the Federal Register on January 4, 2006. This rule applies to systems that use surface water or groundwater under the direct influence of surface water. The purpose of the LT2ESWTR is to reduce illnesses linked with Cryptosporidium and other disease-causing microorganisms in drinking water. The rule supplements existing regulations by targeting additional Cryptosporidium treatment

requirements to higher risk systems. Other pathogens may also be included in this rule, if information on occurrence, health effect, and treatment demonstrate the need for these regulations.

Quick Reference Guides to LT2ESWTR Rule can be found on the EPA website: http://water.epa.gov/lawsregs/rulesregs/sdwa/lt2/compliance.cfm

9.2.7.3.1 Requirement 1 - Source Water Monitoring

Both filtered and unfiltered surface water/GWUDI systems must conduct a 24-month monitoring survey of their source water for Cryptosporidium. The action bin assignment is based upon sampling the source water for Cryptosporidium, E. coli, and turbidity on a predetermined schedule for 24 months. The Rule specifies testing with USEPA methods 1622 and 1623. Either of the following protocols may be used to determine action bin assignment:

- Based upon the highest 12-month running annual average of monthly Cryptosporidium samples.
- Based on two-year mean for monitoring conducted twice per month for 24 months.

Systems having at least 24 measurement results, but fewer than 48, would compute the average result for each set of 12 consecutive results. Systems having 48 or more measurements would compute the mean.

Systems may use previously collected data (i.e., grandfathered data) to determine their bin classification instead of monitoring if specified criteria are met. Filtered systems must also record source water E. coli and turbidity levels.

9.2.7.3.2 Requirement 2 - Risk-Based Treatment Requirements

The source water monitoring results will then be used to determine the system's risk "bin" and the level of additional treatment needed, if any, as summarized in Table 9.6. It should be noted that under this rule, USEPA recognizes that UV disinfection is available and feasible. The LT2ESWTR includes tables specifying UV doses needed to achieve up to 3-log inactivation of Giardia, up to 3-log inactivation of Cryptosporidium, and up to 4-log inactivation of viruses.

Table 9.6 - Cryptosporidium Inactivation Requirements

Bin No.	Average Source Water Cryptosporidium	Additional Treatment Requirements		
	Concentration (oocysts/L)	Conventional Filtration, Diatomaceous Earth Filtration, or Slow Sand Filtration	Direct Filtration	
1	< 0.075	No Action	No Action	
2	0.075 to < 1.0	1 - log	1.5 - log	
2	0.075 t0 < 1.0	using any or all of the micro	obial toolbox technologies	
		2 - log	2.5 - log	
		with at least 1-log of treatr	ment accomplished using:	
	3 1.0 to < 3.0	Ozone		
3		Chlorine Dioxide		
		UV		
		Membranes		
		Bag/cartridge filters		
		Bank fil	tration	
		2.5 - log	3.0 - log	
		with at least 1-log of treatr	ment accomplished using:	
		Ozo	ne	
4	≥ 3.0	Chlorine	Dioxide	
-	2 3.0	U	V	
		Memb	ranes	
		Bag/cartric	dge filters	
		Bank fil	tration	

Compliance Status

Data collected from 2010 through 2015 show that the Wichita WTP is in category Bin 1. As a result, the City does not need to achieve any additional Cryptosporidium removal credits. The dates listed in Table 9.8 show that the last round of testing was April 1, 2015.

If higher levels of Cryptosporidium are detected in the future, additional treatment will be required. The City can choose from an array of options listed in the "microbial toolbox", as summarized in Table 9.7. The microbial toolbox provides systems with flexibility in selecting cost-effective LT2ESWTR compliance strategies for Cryptosporidium. The draft Toolbox Guidance Manual provides general information on the LT2ESWTR regulation and treatment requirements and can be found at: http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_toolboxguidancemanual.pdf

The manual also provides guidance on the selection, design, and operation of treatment and management strategies for each of the 15 treatment options in the LT2ESWTR "microbial toolbox" that can be used to comply with treatment requirements under the rule.

Table 9.7 - Microbial Toolbox Options

Toolbox Option	Maximum Cryptosporidium Treatment Credit Possible			
Source Protection and Management Toolbox Options				
Watershed control program	0.5-log			
Alternative source/intake management	No prescribed credit			
	Prefiltration Toolbox Options			
Presedimentation basin with coagulation	0.5-log			
Two-stage lime softening				
Bank filtration				
	Treatment Performance Toolbox Options			
Combined filter performance	0.5-log			
Individual filter performance	0.5-log credit (in addition to 0.5-log combined performance filter credit)			
Demonstration of performance	Credit at discretion of the State			
	Additional Filtration Toolbox Options			
Bag and cartridge filters	Up to 2- to 2.5-log			
Membrane filtration (MF, UF, NF, RO)	Credit at discretion of the State			
Second stage filtration	0.5-log			
Slow sand filters	2.5-log			
Inactivation Toolbox Options				
Chlorine dioxide	Log credit based on measured CT			
Ozone	Log credit based on measured CT			
UV	Log credit based on validated UV dose (reactor validation testing to establish UV dose and operating conditions)			

Additional treatment requirements are based on the assumption that conventional treatment plants with filtration performance in compliance with the IESWTR achieve an average of 2-log removal of Cryptosporidium. Given this, the total Cryptosporidium removal requirements for conventional treatment action bins 2 - 4 in Table 9.6 correspond to total Cryptosporidium removals of 3, 4, and 4.5-log, respectively.

9.2.7.3.3 Other Requirements

In addition to the Cryptosporidium source water monitoring and removal requirements, the requirements of the LT2ESWTR are intended to ensure that systems maintain adequate protection against microbial pathogens as they take steps to reduce formation of disinfection byproducts. Key provisions of the proposed LT2ESWTR relating to this effort includes:

- Covering, treating, or implementing a risk management plan for uncovered finished water reservoirs. PWSs must notify the State if they use uncovered finished water storage facilities no later than April 1, 2008. PWSs must meet this requirement or be in compliance with a Stateapproved schedule for meeting these requirements no later than April 1, 2009.
- Disinfection profiling and benchmarking to assure continued levels of microbial protection while PWSs take the necessary steps to comply with new disinfection byproduct standards.

9.2.7.3.4 Compliance Timeline

The standard compliance timeline for "Schedule 1" systems (those serving a population of \geq 100,000) is detailed in Table 9.8 and shows the last round of source water monitoring was in April 2015.

Table 9.8 - LT2ESWTR Schedule 1 Compliance Dates

July 1, 2006	Systems must submit their: Sampling schedule that specifies the dates of sample collection and location of sampling for initial source water monitoring to USEPA electronically; or Notify USEPA or the state of the system's intent to submit results for grandfathering data; or Notify USEPA or the state of the system's intent to provide at least 5.5-log of treatment for Cryptosporidium.
October 1, 2006	No later than this month systems must begin 24 months of source water monitoring.
December 1, 2006	No later than this date, systems must submit monitoring results for the data they want to have grandfathered.
December 10, 2006	System submits results for the first month of source water monitoring.
April 1, 2006	No later than this month, systems must notify the USEPA or the state of all uncovered treated water storage facilities.
September 1, 2008	No later than this month, systems must complete their initial round of source water monitoring.
March 1, 2009	No later than this month, filtered systems must report their initial bin classification to the USEPA or the state for approval.
April 1, 2009	No later than this date, uncovered finished water storage facilities must be covered, or the water must be treated before entry into the distribution system, or the system must be in compliance with a state-approved schedule.
March 31, 2012	Systems must install and operate additional treatment in accordance with their bin classification.
January 1, 2015	Systems must submit their sampling schedule that specifies the dates of sample collection and location of sampling for the second round of source water monitoring to the state.
April 1, 2015	Systems must begin their second round of source water monitoring. Based on the results, systems must re-determine bin classification and provide additional Cryptosporidium treatment, if necessary.

9.2.7.4 Stage 1 Disinfectants/Disinfection Byproducts Rule

Stage 1 of the Disinfectants/Disinfection Byproducts Rule (Stage 1 D/DBP Rule) was finalized on December 16, 1998, and became effective for PWSs serving more than 10,000 people on January 1, 2002. The Stage 1 D/DBP Rule is part of the Microbial Disinfectant Byproducts (M/DBP) cluster of rules. The intent of the M/DBP cluster is to balance the risk of microbial disease outbreaks against the risks associated with disinfection and their byproducts.

The requirements of the Stage 1 D/DBP Rule are summarized in Table 9.9. Under the Stage 1 D/DBP Rule, large surface water plants are required to take four samples per plant per quarter. At least 25 percent of these samples are to be taken from the locations representative of the maximum residence time with the remainder representing the average residence times. Compliance with the maximum residual disinfectant level (MRDL) is based upon a running annual average, computed quarterly.

Table 9.9 - Stage 1 D/DBP Rule MCL and MRDL

Constituent	Concentration (mg/L)	
Constituent	MCL	MRDL
Total Trihalomethanes (TTHM)	0.08	
Haloacetic Acids (HAA5)	0.06	
Bromate Ion (BrO3-)	0.01	
Chlorite Ion (CIO2-)	1	
Free Chlorine ¹		4
Chloramines 1,2		4
Chlorine Dioxide		0.8

Notes:

- 1. As total chlorine.
- 2. Sum of mono-, di-, tri-chloroacetic acids, and mono- and di-bromoacetic acids.

Compliance Status

Total Trihalomethane (TTHM) and Haloacetic Acid (HAA5) data for 2010 through 2014 are well below regulatory limits. HAA5 and TTHM values ranged between 7 and 15 μ g/L and 15 and 28 μ g/L in the distribution system, respectively. The Wichita WTP is in full compliance with regards to disinfection byproducts.

The distribution of DBP species was also evaluated. Of the HAA species, dichloroacetic acid and dibromoacetic acid are typically the highest and represent 80 percent of HAA5. Chloroform typically represents approximately 20 percent of the TTHM species, showing that bromide is present and having an impact resulting in the formation of the three brominated species. This data indicates that treatment is doing a good job with removing DBP precursor material.

9.2.7.4.1 Disinfection Byproduct Precursor Removal

In addition to establishing the MCLs and MRDLs, the Stage 1 D/DBPR requires the reduction of DBP precursors. The treatment technique specified is termed enhanced coagulation or enhanced softening and uses total organic carbon (TOC) as a surrogate for natural organic matter (a DBP precursor material). Source water TOC concentration of >2.0 mg/L triggers implementation of this treatment technique. The Rule specifies the percentage of influent TOC that must be removed based on the raw water TOC and alkalinity levels, as shown in Table 9.10.

Table 9.10 - Stage 1 D/DBP Required Removal of TOC by Enhanced Coagulation

Raw Water TOC	Source Water Alkalir ter TOC (mg/L as CaCO ₃)		
(mg/L)	0 to 60	>60 to 120	>120
>2.0 – 4.0	35.0%	25.0%	15.0%
>4.0 to 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Conventional treatment plants are required to monitor TOC concentrations by taking one "paired" sample per month. A paired sample consists of simultaneously measuring the TOC in a treated water sample (prior to the point of combined filter effluent turbidity monitoring) and the TOC in a source water sample (prior to any treatment). One source water alkalinity sample per month is also taken at the same time and location as the source water TOC sample. Reduced monitoring (per quarter) is permitted if the average annual treated water TOC is <2.0 mg/L for two consecutive years or <1.0 mg/L for one year. Compliance with the TOC requirement is calculated with a running annual average, computed quarterly.

Compliance Status

Raw water TOC data for the Wichita WTP typically ranges between 3 and 8 mg/L. The raw water alkalinity is always greater than 120 mg/L; therefore, a 25 percent TOC reduction is required for most sampling periods, based on raw water TOC and alkalinity. The TOC reduction at the Wichita WTP ranges between 25 to 45 percent. As a result, the Wichita WTP is in compliance with regards to TOC reduction.

9.2.7.4.2 Alternative Compliance

The IESWTR also provides alternative compliance criteria (to TOC removal) that are separate and independent of the Step 2 enhanced coagulation procedure and the enhanced softening alternative performance criteria, from the treatment technique requirements provided certain conditions are met:

- Source water TOC <2.0 mg/L based on monthly monitoring calculated quarterly as a running annual average of all measurements.
- Finished water TOC <2.0 mg/L based on monthly monitoring calculated quarterly as a running annual average of all measurements.
- Source water specific ultraviolet absorption (SUVA) is less than or equal to 2.0 L/mg-m based on monthly monitoring calculated quarterly as a running annual average of all measurements. SUVA

is equal to UV absorption at 254 nm (UV254) divided by the dissolved organic carbon (DOC) concentration.

- Finished Water SUVA is less than or equal to 2.0 L/mg-m based on monthly monitoring calculated quarterly as a running annual average of all measurements.
- Source water TOC <4.0 mg/L; Source water alkalinity >60 mg/L as CaCO3; TTHM <0.040 mg/L; HAA5 <0.030 mg/L based on monthly monitoring for TOC and alkalinity or quarterly monitoring for TTHMs and HAA5, calculated quarterly as a running annual average of all measurements.
- TTHM <0.040 mg/L; HAA5 <0.030 mg/L based on monitoring for TTHMs and HAA5, calculated quarterly as a running annual average of all measurements.

Following a one-year monitoring period, systems that do not satisfy the TOC removal requirements or the alternative compliance criteria must conduct jar testing (Step 2) to determine alternative compliance criteria for TOC removal, if they are not practicing enhanced softening. Under the Step 2 enhanced coagulation protocol, the alternative enhanced coagulation compliance criteria for TOC removal are defined either as:

• The dose of coagulant that achieves the percent removal dictated by the TOC removal matrix.

- OR -

• The percent TOC removal occurring at the point of diminishing return (PODR) for the coagulant. The PODR is defined as the point on the TOC removal-vs-coagulant addition plot where the slope changes from greater than 0.3/10 (mg/L TOC removal / mg/L coagulant dose) to less than 0.3/10 and stays at less than 0.3/10 until the target pH is reached.

If softening systems cannot meet the Step 1 TOC removal requirements, they must meet one of the following three alternative enhanced softening compliance criteria based on monthly monitoring calculated quarterly as a running annual average of all measurements.

- Produce a finished water with a SUVA <2.0 L/mg-m;
- Remove a minimum of 10 mg/L magnesium hardness (as CaCO₃); or
- Lower alkalinity to less than 60 mg/L as CaCO₃.

9.2.7.5 Stage 2 Disinfection/Disinfection Byproducts Rule

The Stage 2 Disinfectants/Disinfection Byproducts Rule (Stage 2 DBPR) was finalized in December 2005 and published in the Federal Register on January 4, 2006. Compliance monitoring for the Stage 2 DBPR started in 2012 first for systems serving populations greater than 100,000.

All PWS serving populations greater than 500 people and using a primary disinfectant other than UV light are subject to the Stage 2 DBPR. The purpose of this Rule is to strengthen the Stage 1 D/DBPR requirements and reduce occurrences of disinfection byproducts concentration spikes in distribution systems. The MCLs for TTHMs and HAAs remain the same as those in the Stage 1 D/DBP Rule (80 and 60 µg/L respectively), but the manner in which compliance is calculated has changed.

For Stage 2, the MCLs for TTHMs and HAAs must be met as a locational running annual average (LRAA) – the average concentration at each monitoring location, rather than as the running annual average (RAA) of the system as a whole. Furthermore, samples must be taken during peak months of TTHM and HAA occurrence. The new compliance requirements are meant to enforce a reduction of average DBP concentrations at peak locations and peak times. For the compliance calculation, samples are taken at each monitoring location. The LRAA is calculated as the average of the most recent sample and the three preceding samples.

Compliance monitoring under the Stage 2 DBP Rule is preceded by an Initial Distribution System Evaluation (IDSE) study to select site-specific optimal sampling points for capturing peak disinfection byproduct concentrations.

The IDSE requirements can be met by one of three different criteria as required by the Stage 2 Rule.

- Standard Monitoring Plan (SMP) A distribution system sampling plan that has been developed
 by the USEPA and includes one year of sampling. The sampling requirements vary based on
 population served.
- System Specific Study (SSS) The use of historical data that exceeds the SMP data requirements
 or the use of a calibrated hydraulic model and one round of sampling to determine compliance
 monitoring locations.
- 40/30 Certification Two years of data that show that trihalomethane (THM) and HAA samples
 have never exceeded 40 μg/L and 30 μg/L respectively in the distribution system. If 40/30
 certification is met, systems are not required to perform the IDSE.

After compliance monitoring begins, the Stage 2 DBPR requires the PWS to calculate operational evaluation levels (OEL) after every quarterly sample. The OEL is meant to prevent MCL violations by providing an early warning of possible future violations. If the OEL exceeds the MCL, the PWS must provide a report to the administering agency detailing the changes it is going to make in order to avoid an MCL violation.

9.2.7.5.1 Compliance Timeline

The standard compliance timeline for "Schedule 1" systems (those serving a population of $\geq 100,000$) is detailed in Table 9.11.

Table 9.11 - DBPR2 Schedule 1 Compliance Dates

Compliance Date	Requirement
	Systems must submit to the USEPA or state primacy agency either a:
January 4, 2006	Standard monitoring plan (SMP),
January 4, 2006	System-specific study (SSS) plan, or
	40/30 certification (1)
October 1, 2007	Systems conducting SMP or SSS begin collecting samples in accordance with their approved plan.
September 30, 2008	No later than this date, systems conducting SMP or SSS complete their monitoring or study.
January 1, 2009	No later than this date, systems conducting SMP or SSS must submit their IDSE report.
April 1, 2009	Consecutive systems must begin monitoring for chlorine or chloramines as specified under the Stage 1 DBPR.
	No later than this date, systems must:
April 1, 2012	Complete their Stage 2 DBPR Compliance Monitoring Plan
	Begin complying with monitoring requirements
January 1, 2013	Systems must begin complying with rule requirements to determine compliance with the operational evaluation levels for TTHMs and HAA5s.

Notes:

9.2.8 Unregulated Contaminant Monitoring Rule (UCMR)

The Unregulated Contaminant Monitoring (UCMR) was established by the EPA to collect data for contaminants present in drinking water that do not have health-based standards set under the SDWA. The data and monitoring assists in determining whether or not to regulate those contaminants to protect public health. EPA is requiring select PWSs to monitor for UCMR contaminants using analytical methods developed by EPA, consensus organizations or both.

^{1.} A system that during a specific time period has all individual Stage 1 DBPR1 compliance samples ≤0.040 mg/L for TTHM and 0.030 mg/L HAA5 and has no monitoring violations during that same time period.

Every five years EPA reviews the list of contaminants, largely based on the Contaminant Candidate List. The SDWA Amendments of 1996 provide for:

- Monitoring no more than 30 contaminants per 5-year cycle.
- Monitoring only a representative sample of PWSs serving less than 10,000 people.
- Storing analytical results in a National Contaminant Occurrence Database (NCOD).

The UCM program progressed in several stages. The history of the UCM program includes:

- UCM Rounds 1 & 2 (1988-1997): State drinking water programs managed the original program and required PWSs serving more than 500 people to monitor contaminants.
- UCMR 1 (2001-2005): the SDWA Amendments of 1996 redesigned the UCM program to incorporate a tiered monitoring approach. The rule required all large PWS and a nationally representative sample of small PWSs serving less than 10,000 people to monitor the contaminants.
- UCMR 2 (2007-2010): EPA manages the second monitoring cycle. This monitoring cycle establishes a new set of unregulated contaminants.
- UCMR 3 was published on May 2, 2012 and requires monitoring for 30 contaminants (28 chemicals and two viruses) between 2012 and 2016 using analytical methods developed by EPA.
 Approximately 6,000 PWSs participated in UCMR3.
- UCMR 4 is expected to occur between 2017 and 2021.

Compliance Status

The UCMR2 contaminants are summarized below in Table 9.12. UCMR2 contaminant data was collected on June 22, 2009; October 21, 2009; January 21, 2010; April 04, 2010; and June 26, 2010. Finished water was below the detection limit for all samples collected.

The UCMR3 fact sheet is provided by the US EPA (https://www.epa.gov/sites/production/files/2015-10/documents/ucmr3_factsheet_general.pdf); the contaminants are summarized below in Table 9.13.

Table 9.12 - UCMR 2 Contaminants

Assessment Monitoring List 1	Screening Survey List 2
Contaminant	Contaminant
Dimethoate	Acetochlor
Terbufos sulfone	Alachlor
	Metolachlor
Five Flame Retardants	Six Acetanilide Degradates
2,2',4,4'-tetrabromodiphenyl ether (BDE-47)	Acetochlor ethane sulfonic acid (ESA)
2,2',4,4',5-pentabromodiphenyl ether (BDE-99)	Acetochlor oxanilic acid (OA)
2,2',4,4',5,5'-hexabromobiphenyl (HBB)	Alachlor ethane sulfonic acid(ESA)
2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153)	Alachlor oxanilic acid (OA)
2,2',4,4',6-pentabromodiphenyl ether (BDE-100)	Metolachlor ethane sulfonic acid(ESA)
	Metolachlor oxanilic acid (OA)
Three Explosives	Six Nitrosamines
1,3-dinitrobenzene	N-nitroso-diethylamine (NDEA)
2,4,6-trinitrotoluene (TNT)	N-nitroso-dimethylamine (NDMA)
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	N-nitroso-di-n-butylamine (NDBA)
	N-nitroso-di-n-propylamine (NDPA)
	N-nitroso-methylethylamine (NMEA)
	N-nitroso-pyrrolidine (NPYR)

Table 9.13 - UCMR 3 Contaminants

Assessment Monitoring (List 1 Contaminants)									
Seven VOCs	Six Metals								
1,2,3-trichloropropane	vanadium								
1,3-butadiene	molybdenum								
chloromethane (methyl chloride)	cobalt								
1,1-dichloroethane	strontium								
bromomethane (methyl bromide)	chromium-3								
chlorodifluoromethane (HCFC-22)	chromium-6								
bromochloromethane (halon 1011)									
One SOC and Oxyhalide Anion	Six Perfluorinated Compounds								
1,4-dioxane	perfluorooctanesulfonic acid (PFOS)								
chlorate	perfluorooctanoic acid (PFOA)								
	perfluorononanoic acid (PFNA)								
	perfluorohexanesulfonic acid (PFHxS)								
	perfluoroheptanoic acid (PFHpA)								
	perfluorobutanesulfonic acid (PFBS)								
Screening Survey (L	ist 2 Contaminants)								
Seven Hormones									
17-β-estradiol									
17- α -ethynylestradiol (ethinyl estradiol)									
16-α-hydroxyestradiol (estriol)									
equilin									
estrone									
testosterone									
4-androstene-3,17-dione									

UCMR3 contaminant data was collected on December 10, 2014; March 11, 2015; March 12, 2015; and June 24, 2015. Finished water was below the detection limit for most samples collected. The following list shows detectable concentrations:

	Max Detectable
Contaminant	Concentration (µg/L)
Total Chromium	0.27
Hexavalent Chromium	0.058
Vanadium	1.7
Strontium	330
Molybdenum	3.3

Strontium is considered an USEPA Cancer Class D (not classifiable as to human carcinogenicity) (USEPA, 2012); however, there is not a federal drinking water standard for strontium at this time. The EPA has set a health reference level for strontium. As of October 2014 the health reference level for strontium was listed as 1.5 mg/L. These concentration for strontium ranged between non-detect and 330 μ g/L.

There is not a federal drinking water standard or a health advisory level for vanadium at this time. The U.S. EPA's current reference concentration for vanadium indicates that ongoing exposure to vanadium at levels of more than 21 μ g/L per day may lead to negative health effects. Vandium ranged between non-detect and 1.7 μ g/L.

According to recent World Health Organization studies, molybdenum is present in surface waters used as drinking water supplies, and it can be present in finished water at levels less than $10 \,\mu\text{g/L}$. As part of its Third Unregulated Contaminant Monitoring Rule (UCMR3) testing, the EPA is examining how prevalent molybdenum is in U.S. drinking water supplies and at what level it occurs. There is not a federal drinking water standard for molybdenum at this time; however the EPA has set health advisory levels. The current lifetime HAL (non-enforceable recommendation) for molybdenum is $40 \,\mu\text{g/L}$ with the one-day and 10-day HALs are both $80 \,\mu\text{g/L}$. Molybdenum ranged between non-detect and $3.3 \,\mu\text{g/L}$.

9.3 Potential Future Regulations

9.3.1 Contaminant Candidate List (CCL)

The EPA uses the Contaminant Candidate List (CCL) to prioritize research and data collection efforts in order to determine whether a specific contaminant should be regulated. The contaminants on the list are

known or anticipated to occur in PWSs, but are currently unregulated. The EPA periodically publishes the CCL and decides whether to regulate at least five or more contaminants on the list (called Regulatory Determinations). These new rules will further strengthen existing drinking water standards and thus enhance public health protection for many water systems.

The first CCL of 60 contaminants was published in March 1998. In February 2005, the EPA published the second CCL of 51 (of the original 60) unregulated contaminants from the first CCL, including nine microbiological contaminants and 42 chemical contaminants or contaminant groups. The microbiological contaminants included cyanobacteria, other freshwater algae, and their toxins.

The EPA announced the third draft of the Drinking Water Contaminant Candidate List (CCL 3) in February 2008. It includes 116 contaminants, including 104 chemicals or chemical groups and 12 microbiological contaminants. Several new chemical contaminants were added to the list, including three cyanotoxins (Anatoxin-a, Microcystin-LR, and Cylindrospermopsin).

CCL3 is the first CCL to use a process for screening contaminants for the list based on a formal National Drinking Water Advisory Council (NDWAC) recommendation. The USEPA also stated that the CCL3 incorporated recommendations from different groups, including the American Metropolitan Water Agencies (AMWA), American Waterworks Association (AWWA), National Research Council, and the National Drinking Water Advisory Council. AMWA recommended that three nitrosamines, N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA) and N-nitrosodi-n-propylamine (NDPA) be added to the list. Their letter stated that as systems turn to chloramination as a result of the Stage 2 MDBP rules, understanding more about these and other nitrosamine DBPs are critical, since their occurrence in drinking water may increase.

9.3.1.1 NDMA

NDMA is part of the Nitrosamine family of N-DBPs, where the characteristic functional group is nitrogen based. The family includes NDEA, NDMA, N-nitroso-di-n-butylamine (NDBA), NDPA, N-nitrosomethylethylamine (NMEA), and N-nitrosopyrrolidine (NPYR). NDMA is the most frequently found compound, and as a result, the most studied. Research studies show that NDMA is formed during the chloramination of natural waters with organic matter. Toxicity studies indicate that the cancer potencies are several orders of magnitude higher than TTHM and HAA5, resulting in a lifetime cancer risk at low ng/L levels.

The organic nitrogen-containing compounds that might act as precursors for nitrosamine formation during chloramination are numerous. Removal of these precursors prior to chloramination is required to reduce

NDMA formation. DBP reduction strategies typically include improved coagulation, PAC, GAC, and preoxidation.

Compliance Status

NDMA and other Nitrosamine family compounds were not detected in the Wichita WTP finished water. The suggested regulatory MCL for NDMA is between 2 and 10 ng/L.

9.3.2 Perchlorate Regulations

Perchlorate is not currently regulated by the USEPA. In 2005, EPA announced it had set a reference dose of 0.0007 mg/kg for perchlorate, following a recommendation from the National Academies of Science. This translates to a Drinking Water Equivalent Level of 24.5 ppb.

Perchlorate was absent from the CCL2 list, but included in the draft CCL3 to determine if it would require future regulations. In 2008, USEPA staff indicated that federal regulation under the current administration was unlikely. USEPA, however, continued to collect data on total perchlorate exposure, including the release of the FDA's Total Diet Study. Legislation that would provide USEPA with two-and-a-half years to promulgate a final national drinking water regulation for perchlorate was approved by a House subcommittee in early November 2007 (H.R. 1747) would require USEPA to propose a perchlorate MCL one year after the bill's enactment and promulgate a final national regulation 18 months thereafter.

On January 7, 2011, the Office of Environmental Health Hazard Assessment (OEHHA) released a draft public health goal (PHG) of 1 μ g/L for perchlorate in drinking water. The proposed goal would revise the existing PHG for perchlorate, which was set at 6 μ g/L in 2004. Release of the proposed revision begins a 45-day public comment period.

On February 2, 2011, EPA Administrator Lisa Jackson announced in a press release and in her testimony to the Senate Committee on Environment and Public Works that the agency will move forward to develop a regulation for perchlorate in drinking water. The decision to undertake a first-ever national standard for perchlorate reverses a decision made by the previous administration and comes after Administrator Jackson ordered EPA scientists to undertake a thorough review of the emerging science of perchlorate. EPA will propose the perchlorate standard in 2017.

Perchlorate is both a naturally occurring and man-made chemical, and scientific research indicates that it may impact the normal function of the thyroid, which produces important developmental hormones.

Thyroid hormones are critical to the normal development and growth of fetuses, infants and children.

Based on this potential concern, EPA will move forward with proposing a formal rule. This process will include receiving input from key stakeholders as well as submitting any formal rule to a public comment process.

Compliance Status

This regulation will likely have minimal impact on Wichita WTP due to low detection levels.

9.3.3 Volatile Organic Compounds

On February 2, 2011, EPA Administrator Lisa Jackson announced that the agency will move toward establishing one drinking water standard that will address a group of up to 16 carcinogenic VOCs, including trichloroethylene (TCE), tetrachloroethylene (PCE) and other regulated and unregulated contaminants that are discharged from industrial operations. The VOC standard will be developed as part of EPA's new strategy for drinking water, announced by the administrator in March 2010. A key principle of the strategy is to address contaminants as groups rather than individually in order to provide public health protections more quickly and also allow utilities to more effectively and efficiently plan for improvements.

Compliance Status

Data collected between 2010 and 2014 showed non-detect for each VOC sample. As a result, this regulation will likely have minimal impact on Wichita WTP.

9.3.4 Perfluorinated Compounds

Perfluorinated Compounds (PFCs), more commonly referred to as Poly- and perfluoroalkyl substances (PFASs), are a diverse group of compounds resistant to stains, heat, water, and oil. For decades, they have been used in hundreds of industrial applications and consumer products such as fire-fighting foams, Teflon, carpeting, apparels, upholstery coatings, food paper wrappings, and metal plating. PFCs have been found at very low levels both in the environment and in the blood samples at every level of the food chain.

One of the most frequently used classes of PFASs are the perfluoroalkyl acids (PFAAs), whose structure consists of a completely fluorinated carbon chain of varying length and a charged functional group, such as carboxylic or sulfonic acid. The most notable PFAAs are perfluorooctanoic acid (PFOA or C8) and perfluorooctane sulfonate (PFOS), but there are many others, a selection of which are shown in the list below. PFAAs are extremely recalcitrant and persistent in the environment and occur ubiquitously in environments worldwide.

Chemical Name	Abbreviation	$\underline{\mathbf{M}}\mathbf{W}$	<u>Formula</u>
Perfluorobutanoic acid	PFBA	214	C3F7COOH
Perfluoropentanoic acid	PFPeA	264	C4F9COOH
Perfluorohexanoic acid	PFHxA	314	C5F11COOH
Perfluoroheptanoic acid	PFHpA	364	C6F13COOH
Perfluorooctanoic acid	PFOA	414	C7F15COOH
Perfluorononanoic acid	PFNA	464	C8F17COOH
Perfluorodecanoic acid	PFDA	514	C9F19COOH
Perfluoroundecanoic acid	PFUnA	564	C10F21COOH
Perfluorododecanoic acid	PFDoA	614	C11F23COOH
Perfluorobutane sulfonate	PFBS	300	C4F9SO3H
Perfluorohexane sulfonate	PFHxS	400	C6F13SO3H
Perfluorooctane sulfonate	PFOS	500	C8F17SO3H
Perfluorodecane sulfonate	PFDS	600	C10F21SO3H

There are not currently any federal regulations limiting PFASs in water, but the EPA is considering whether to establish Maximum Contaminant Levels for PFASs in drinking water. EPA set provisional health advisory (HA) levels for PFOS at $0.2~\mu g/L$ and for PFOA at $0.4~\mu g/L$ based on short-term exposure concerns, and both are included in the draft Contaminant Candidate List 4 (EPA 2016). Many states have their own drinking water and groundwater guidelines to limit PFOA and PFOS, including Minnesota, New Jersey, and North Carolina. Kansas does not yet have any regulatory requirements.

PFCs were included in the EPA's Third Unregulated Contaminant Monitoring Rule testing in order to determine how prevalent certain perfluorinated compounds are in U.S. drinking water supplies and at what level they appear.

Following that testing, on May 19, 2016, the EPA released health advisories for perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), making a lifetime health advisory for each compound, or a sum total of the two, of 0.07 parts per billion (70 ng/L).

Conventional drinking water treatment processes (coagulation, sedimentation, filtration, chloramination) are not effective for PFAS removal. Furthermore, advanced oxidation processes (ozone, UV/H2O2) are unable to oxidize PFASs because of the strength of the carbon-fluorine bond. Treatment processes that

have shown promise for PFAS removal include activated carbon adsorption, anion exchange, nanofiltration, and reverse osmosis.

The UCMR3 testing data show non-detect of PFASs, but that could be the result of detection limit, as the units were measured in $\mu g/L$. Additional testing is recommended to confirm concentration of these compounds.

9.4 Summary

The Wichita WTP is currently meeting all State and Federal drinking water regulations. The data collected as part of UCMR3 show that possible future regulatory requirements with regards to chromium, NDMA, PFAS, and VOCs will have minimal impact on the WTP.

* * * * *

2016 Water Master Plan Future Growth

10.0 FUTURE GROWTH

This section of the report discusses the future growth demand allocation in the distribution system hydraulic model. The water demand projections included in Section 3.0 for each planning period are applied in the model to the future growth areas provided by the Wichita-Sedgwick County Metropolitan Area Planning Department (MAPD) based on the population growth/projections (also provided by MAPD). A summary of the customer water sales projections through year 2045 and corresponding average day, maximum day, and population projections is listed in Table 10.1.

10.1 Population and Demand Allocation

Population projections through year 2045 are allocated to the future growth areas. The anticipated growth pattern provided by the City and MAPD places more emphasis on infill utilization than future development beyond the City's existing water service area as illustrated in Figure 10.1, but neither is a prerequisite for the other. Growth of either type, infill or development, can happen at different rates and at different times. Since the anticipated rate at which each growth area reaches buildout capacity was not provided, the population allocation for future growth assumes infill utilization occurs before future development beyond the City's existing water service area.

This allocation approach is adaptable, repeatable, and easy to maneuver future water demand (location, amount, and planning period) and corresponding capital improvements if future development beyond the existing water service area occurs prior to or in parallel with infill growth. The planning period in which corresponding capital improvements are needed can be accelerated as improvements are sized to support the year 2045 water demand projection. For the purposes of this report, related figures and tables, future development beyond the existing water service area is referred to as peripheral growth.

Based on the information provided by the City and MAPD, infill growth represents approximately 71 percent of the total growth area and peripheral growth represents approximately 29 percent. The population allocation per planning year and by pressure zone is summarized in Table 10.2. The corresponding average day and maximum day demand allocations per planning period and by pressure zone are listed in Tables 10.3 and 10.4 respectively and summarized below:

- Year 2020
 - \circ Population = 416,652
 - o Demands (average day and maximum day) = 67 MGD and 120 MGD
- Year 2035

2016 Water Master Plan Future Growth

- o Population = 485,483
- O Demands = 70 MGD and 127 MGD
- Year 2016
 - \circ Population = 537,603
 - o Demands = 71 MGD and 128 MGD

The average day water demand projections include a 1 percent drought and targets a 0.35 percent conservation effort through year 2060. The population projections represent a growth rate of 1.25 percent for the Wichita growth areas. Therefore, the demand allocation for future growth applied in the model is a based on the resulting per-capita water usage; hence the non-linear relationship in population versus demand.

Some of the peripheral growth areas border and/or extend into neighboring water districts and/or municipalities; capital improvements extending into these areas are identified in the capital improvements plan in Section 14.0.

* * * * *

Table 10.1 Water Master Planning Demand Allocation

			Average Day Sales	Projections ² (MGD)	Projections ⁴						
Year ¹	Wholesale Retail Avera				Average Day	Maximum Day	Maximum Day	D1-416	Average Day Water		
		Residential	Commercial	Sprit	Nonrevenue ³	Demand (MGD)	Multiplier	Demand⁵ (MGD)	Population ⁶	Usage ⁷ (gpcd)	
2015	4.0	22.2	15.6	3.0	4.8	49.7	1.6	78.0	395,949	115	
2016	7.0	31.8	18.5	2.70	5.5	65.5	1.8	117.9	400,006	146	
2020	7.0	33.5	19.7	0.81	5.9	66.9	1.8	120.3	416,652	144	
2035	7.0	35.0	21.3	0.81	6.2	70.3	1.8	126.5	485,483	130	
2045	7.0	35.1	21.9	0.81	6.3	71.1	1.8	127.9	537,603	119	

- 1. Data listed for 2015 is historical; all other years are projected values.
- 2. Average day residential and commercial sales projections in Table 3.6 adjusted to match average day demand projections from the Water Resources Plan. Wholesale projections listed above represents the total demand wholesale customer demand also listed in Table 3.6.
- 3. Nonrevenue at 11 percent applied to residential and commercial average day sales.
- 4. Demand projections from City's Water Resources Plan and as listed in Table 3.6; population projections provided by MAPD for Segdwick County.
- 5. Maximum day demand projections include 2.5 MGD for Spirit; CoW is responsible for providing all Spirit water demand if reuse capability cannot be provided.
- 6. Population projections provided by City.
- 7. Water usage does not include wholesale customers; water usage is intended to characterize customers within the City's water service area served by the City.

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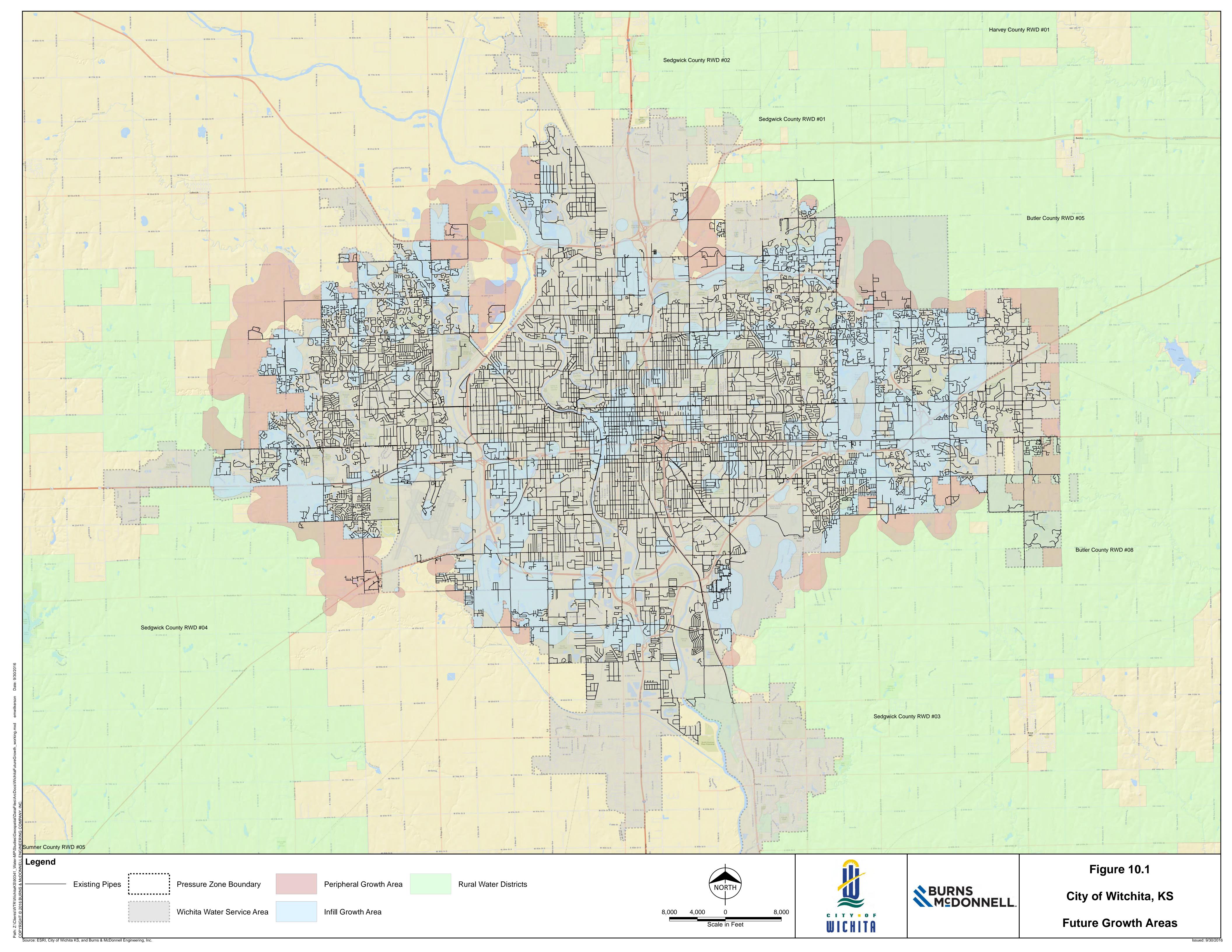


Table 10.2
Future Growth Population Allocation per Planning Period

						Pressur	e Zone						Subtotal Popu	lation Growth	Total	Cummulative
Year	Hess			East			Northeast			West Maple		West Maple		Peripheral	Population	Population
	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Growth	Growth ¹
2016	2,648		2,648	1,192		1,192	155		155	62		62	4,057		4,057	400,006
2020	10,867		10,867	4,892		4,892	635		635	252		252	16,646		16,646	416,652
2035	44,934		44,934	20,228		20,228	2,626		2,626	1,044		1,044	68,831		68,831	485,483
2045	3,065	36,270	39,335	1,380	8,030	9,410	179	3,125	3,304	71		71	4,695	47,425	52,120	537,603

City of Wichita, Kansas

^{1.} A base population of 395,949 is included in the 2016 population projection.

Table 10.3
Future Growth Average Day Demand Allocation per Planning Period

		Pressure Zone											Matau Haara ¹	Subtotal Demand (MGD)		Total Average
Year		Hess			East			Northeast			West Maple		Water Usage ¹	-		Day Demand
	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	(gpcd)	"""	Peripheral	(MGD)
2016	0.39		0.39	0.17		0.17	0.02		0.02	0.009		0.009	146	0.7		0.7
2020	1.56		1.56	0.70		0.70	0.09		0.09	0.036		0.036	144	2.5		2.5
2035	5.86		5.86	2.64		2.64	0.34		0.34	0.136		0.136	130	9.6		9.6
2045	0.37	4.32	4.69	0.16	0.96	1.12	0.02	0.37	0.39	0.008		0.008	119	0.9	5.7	6.5

1. Water usage does not include wholesale customers; water usage represents residential and commercial customers within the City's water service area served by the City.

Table 10.4
Future Growth Maximum Day Demand Allocation per Planning Period

		Pressure Zone ¹ (MGD)											Total Maximum Day						
Year		Hess			East			Northeast			West Maple		Infill	Infill	Infill Parinhars	Peripheral	Wholesale	Spirit	Demand (MGD)
	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	Infill	Peripheral	Subtotal	1111111	Peripilerai	wildlesale	эрин	Demana (MGD)		
2016	0.7		0.7	0.3		0.3	0.04		0.04	0.016		0.016	1.2		7.0	2.5	10.7		
2020	2.8		2.8	1.3		1.3	0.16		0.16	0.065		0.065	4.5		7.0	2.5	14.0		
2035	10.5		10.5	4.7		4.7	0.62		0.62	0.245		0.245	17.2		7.0	2.5	26.7		
2045	0.7	7.8	8.4	0.3	1.7	2.0	0.04	0.67	0.71	0.015		0.015	1.6	10.2	7.0	2.5	21.3		

Notes:

1. A maximum day demand multiplier of 1.80 is applied to the average day demand allocation.

11.0 FUTURE DISTRIBUTION SYSTEM ANALYSIS

This section of the report discusses the model results and recommended improvements in the distribution system based on the demand projections for years 2020, 2035, and 2045. The improvements are based on the water demand projections discussed in Section 3.0, the hydraulic analysis criteria discussed in Section 5.0, and the future growth allocation discussed in Section 10.0. The model results discussed in this section include pumping, pressure, storage, distribution system hydraulics, and fire flow availability in the distribution system.

The demand conditions evaluated in the model for each planning period includes maximum day, peak hour, minimum hour, and maximum day plus fire flow. The resulting system improvements are required to meet these demand conditions.

11.1 Year 2020 Planning Period

The water demand projections and corresponding demand conditions for the year 2020 planning period are listed below and require approximately 2.4 miles of linear hydraulic related improvements and 4.1 miles of fire flow related improvements to support infill growth within the City's existing water service area:

- Maximum Day = 120 MGD
- Peak Hour = 153 MGD
- Minimum Hour = 59 MGD

11.1.1 Pumping and Pressure

There are no pumping improvements required to meet the projected water demands as all pump stations have adequate pumping capacity to deliver the peak hour and maximum day plus fire flow demand conditions while maintaining pressures greater than 40 psi. Flow and pressure contributions from each pump station and pressure control points in the distribution system are summarized in Tables 11.1 and 11.2. The pressure control points represent locations in the distribution system that City staff use to monitor for pumping and storage operations. The current pressure control points in the distribution system by pressure zone include the following:

- Hess Pressure Zone = Central Avenue and Main Street
 - o Target pressure = 92 psi
 - Most critical control point.
- East Pressure Zone = Harry Street and Webb Road
 - O Desired range = 55 psi to 65 psi

Table 11.1
Year 2020 Pumping and Pressure Results

		Existing Desired	Maxim	um Day	Peak Hour		
Pump Station	Pressure Zone	Range (psi)	Flow (MGD)	Pressure (psi)	Flow (MGD)	Pressure (psi)	
Hess HSPS	Hess	98-103	110.5	99	141.3	101	
Webb Road PS	Northeast	65-85	9.8	91	8.5	77	
37th St BPS	Northeast	note 2	0.0	88	0.0	78	
Webb Road PS	East	55-65	19.3	66	9.7	74	
Southeast BPS	East	note 1	0.0	72	14.8	109	
West Maple BPS	West Maple	75-80	0.7	80	0.7	78	

- 1. 37th St BPS flow is utilized in a supplemental operation to Webb Rd PS; there is no desired disharge pressure range.
- 2. Southeast BPS has been not been utilized by the City; there is no desired discharge pressure range.

Table 11.2
Year 2020 Distribution System Pressure Results

		Evicting Docirod	Maximum Day	Peak Hour
Pump Station	Pressure Zone	Existing Desired Range (psi)	Pressure (psi)	Pressure (psi)
Central & Main	Hess	92	92	92
Kellogg & Webb	Northeast	50-60	65	54
Harry & Webb	East	55-65	61	88
Maple & 167th	West Maple	55-60	63	61

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- Northeast Pressure Zone = Kellogg Avenue and Webb Road
 - O Desired range = 50 psi to 60 psi
- West Maple Pressure Zone = Maple Street and 167th Street
 - O Desired range = 55 psi to 60 psi

The model results under maximum day and peak hour demand conditions are within an acceptable range for pressure from the current desired range. For clarity, the Northeast Tower, new pumps at Webb Road PS for the Northeast pressure zone, and the Southeast BPS are active in this scenario; this is distinctly different from the current mode of operation so not all comparisons to current desired ranges are applicable. When the Northeast Tower, new pumps at Webb Road PS, and Southeast BPS are in service, new desired ranges and operating conditions will need to be established.

Southeast BPS can be used under peak hour demand conditions and, as a result, the discharge pressure at Webb Road PS (East pressure zone pumps) increases to 74 psi, which is 9 psi higher than the current desired range between 55 psi and 65 psi. The average pressure in the East pressure zone under peak hour demands is approximately 89 psi with Southeast BPS on; if the BPS is off and all demand is served by Webb Road PS, then a large area south of Harry Street and east of Greenwich Road experiences low pressure between 25 psi and 35 psi.

Firm capacity is considered the pumping capacity with the largest pump out of service. With respect to the Northeast pressure zone, the firm capacity of Webb Rd PS is approximately 6,500 gpm, which is less than the 2020 maximum day demand of 6,800 gpm. Therefore, flow from 37th St BPS must be relied on to supplement firm capacity conditions for the Northeast pressure zone. As indicated in Section 6.1.3, no conclusions could be made on the pumping capacity of 37th St BPS because SCADA historian data suggests the pump curves have shifted or are influenced by the mechanical governor on Pump No. 1 and should be tested. The results of the pump tests (new pump curves) should be evaluated in the model to determine hydraulic compatibility with Webb Rd PS before determining the need for new pumps, sizing recommendations, and/or the ability of the pump station to support different size pumps based on the year 2045 maximum day demand of 10.8 MGD. New pumps sized at varying flow rates may provide more operational flexibility, versus new pumps each with the same capacity, to meet the range of demands experienced in the Northeast pressure zone and support firm capacity conditions; head conditions for new pumps should be able to overcome headloss in the pressure zone and reach the overflow elevation of the Northeast Tower.

The firm pumping capacities for the Hess and East pressure zones exceed the maximum day demand condition for each planning period. However, the firm pumping capacity with backup power should be increased to deliver peak hour flows plus fire flow requirements at Hess HSPS and at Southeast BPS. This is addressed in further detail in Section 13.0.

11.1.2 Storage

The storage analysis methodology discussed in Section 6.0 is applied for the 2020 planning period and is based on the maximum day demand and minimum storage requirement for fire and equalization. The storage analysis for the Northeast pressure zone is evaluated alone because it has dedicated storage in Webb Road reservoir and in the Northeast Tower (effective storage). Hess, East, and West Maple pressure zones have shared storage at Hess reservoir and are evaluated together. Results of the storage analysis is listed in Tables 11.3 and 11.4 and indicates a storage surplus of 9.7 MG for the Hess, East, and West Maple pressure zones and a storage surplus of 5.7 MG for the Northeast pressure zone; no additional storage is required in the distribution system.

Under minimum hour demand conditions and/or low flow periods and night lasting 4 to 5 hours, the distribution system and Hess HSPS is capable of filling Webb Road reservoir, Woodlawn Tower, and Roosevelt Tower. However, as the water level in Roosevelt Tower approaches 90 percent full, the model results indicate a pressure of 94 psi at Central and Main under a minimum hour system demand of 61.0 MGD. After multiple attempts with different pump combinations and speed settings at Hess HSPS, the model results conclude Hess HSPS cannot fill the towers without exceeding the target pressure of 92 psi at Central and Main; though the ability to completely fill the towers is not an operational requirement, continued use of the towers is sufficient as long as adequate turnover can be maintained. The distribution system and new pumps at Webb Road PS serving the Northeast pressure zone have adequate capacity to fill the Northeast Tower during low demand periods.

11.1.3 Distribution System Hydraulics

There are 17 capital improvements with hydraulic triggers required to support the year 2020 demand projection and infill growth; 14 of these are smaller projects, each less than 200 ft in length, and are attributed to undersized parallel water mains that exhibit velocity greater than 5 fps and headloss greater than 6 ft per 1,000 ft. The headloss is manageable and does not impact distribution system hydraulics greatly, but higher velocities can result in water main breaks during periods of accelerated flows through the system such as fire flow. The larger projects include the following:

Table 11.3
Year 2020 Storage Analysis: Northeast Pressure Zone

Item	Amount based on Effective Storage ¹	Amount based on Total Storage ²		
Fire or Emergency Demand (gpm)	3,500	same		
Duration (hours)	3.0	same		
Fire or Emergency Volume (MG)	0.6	same		
Equalizing Factor (MG/MGD)	0.12	same		
2020 Maximum Day Demand (MG)	9.8	same		
Equalizing Volume (MG)	1.2	same		
Total Storage Volume Required (MG)	1.8	same		
Effective ¹ or Total ² Storage (MG)	7.5	11.0		
Storage Surplus (MG)	5.7	9.2		

- 1. Effective storage = 6.5 MG from Webb Reservoir and 1.0 MG from Northeast Tower; 6.5 MG from Webb Reservoir represents volume of water above 7.0 ft.
- 2. Total storage = 10.0 MGD from Webb Reservoir and 1.0 from Northeast Tower.

Table 11.4
Year 2020 Storage Analysis: Hess, East, and
West Maple Pressure Zones

Item	Amount based on Effective Storage ¹	Amount based on Total Storage ²
Fire or Emergency Demand (gpm)	7,000	same
Duration (hours)	4.0	same
Fire or Emergency Volume (MG)	1.7	same
Equalizing Factor (MG/MGD)	0.13	same
2020 Maximum Day Demand (MG)	110.5	same
Equalizing Volume (MG)	14.4	same
Total Storage Volume Required (MG)	16.0	same
Effective ¹ or Total ² Storage (MG)	25.7	35.1
Storage Surplus (MG)	9.7	19.1

Notes:

- 1. Effective storage = considered the volume above 4 ft in Hess reservoir system and assumes pumps are on above a water level of 7 ft.
- 2. Total storage = 35.1 MG from Hess reservoirs.

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- 2020-Hess-H-16: approximately 1,000 feet of 48-inch pipe is required to convey flow into the southern and eastern parts of Hess pressure zone, notably the suction side of Southeast BPS.
 This improvement ties into the end of the existing 48-inch transmission main at the intersection of Lewis Street and Green Street and connects to CIP 2020-Hess-H-12 discussed below.
 - 2020-Hess-H-12: approximately 2,900 feet of 30-inch pipe is required to convey flow into the southern and eastern parts of Hess pressure zone, notably the suction side of Southeast BPS. This improvement ties into CIP 2020-Hess-H-16, heads south down S Erie Street, east for a short run on E Kellogg St, then south along Lorraine Street and ties into the existing 30-inch water main on Morris Street.
- 2020-Hess-H-15: approximately 5,200 feet of 30-inch pipe is required to convey flow from Hess
 pressure zone to the suction side of Southeast BPS and ties into the existing 24-inch at the
 intersection of Lincoln Street and Woodlawn Street, heads south down Woodlawn then east
 along Harry Street to the 36-inch suction pipe on Governeour Rd.
- 2020-East-H-2: approximately 3,500 feet of 30-inch pipe is required to convey more flow from Southeast BPS down Harry Street. This water main ties into the existing 30-inch water main on Harry Street near Harry Court and extends east down Harry Street and ties into the 20-inch and 16-inch water mains at the intersection of Harry Street and Webb Road.

City staff indicated potential large users often consider the industrial area near the intersection of S Tyler Road and W 31 Street S for their needs; therefore, an additional model simulation determined the available flow by increasing the recommended size of 12-inch to a 16-inch for CIPs 2020-Hess-H-18 (PIPE639) and 2020-Hess-H-19 (PIPE641) for comparison. Pressure at this location under maximum day demand conditions is approximately 74 psi; assuming an allowable pressure drop of 5 psi, which is tolerable for this area of the distribution system, the resulting flow, or demand, for each size is listed below:

- 12-inch (as listed in the CIP) can deliver approximately 1,170 gpm.
- 16-inch can deliver approximately 1,260 gpm.

Base on the results of this analysis, a 16-inch conveys 90 gpm more to this area, therefore, the recommendation for a 12-inch is maintained in the CIP.

11.1.4 Fire Flow

Capital improvement projects with fire triggers total approximately 4.1 miles in length and increase the available fire flow range in adjacent areas between 800 gpm and 1,200 gpm and is adequate for the

residential neighborhoods in which they are located. Available fire flow contours are illustrated in Figure 11.1 for the entire distribution system and include the hydraulic and fire flow related improvements. The fire flow improvements listed below have additional discussion points for the City to consider:

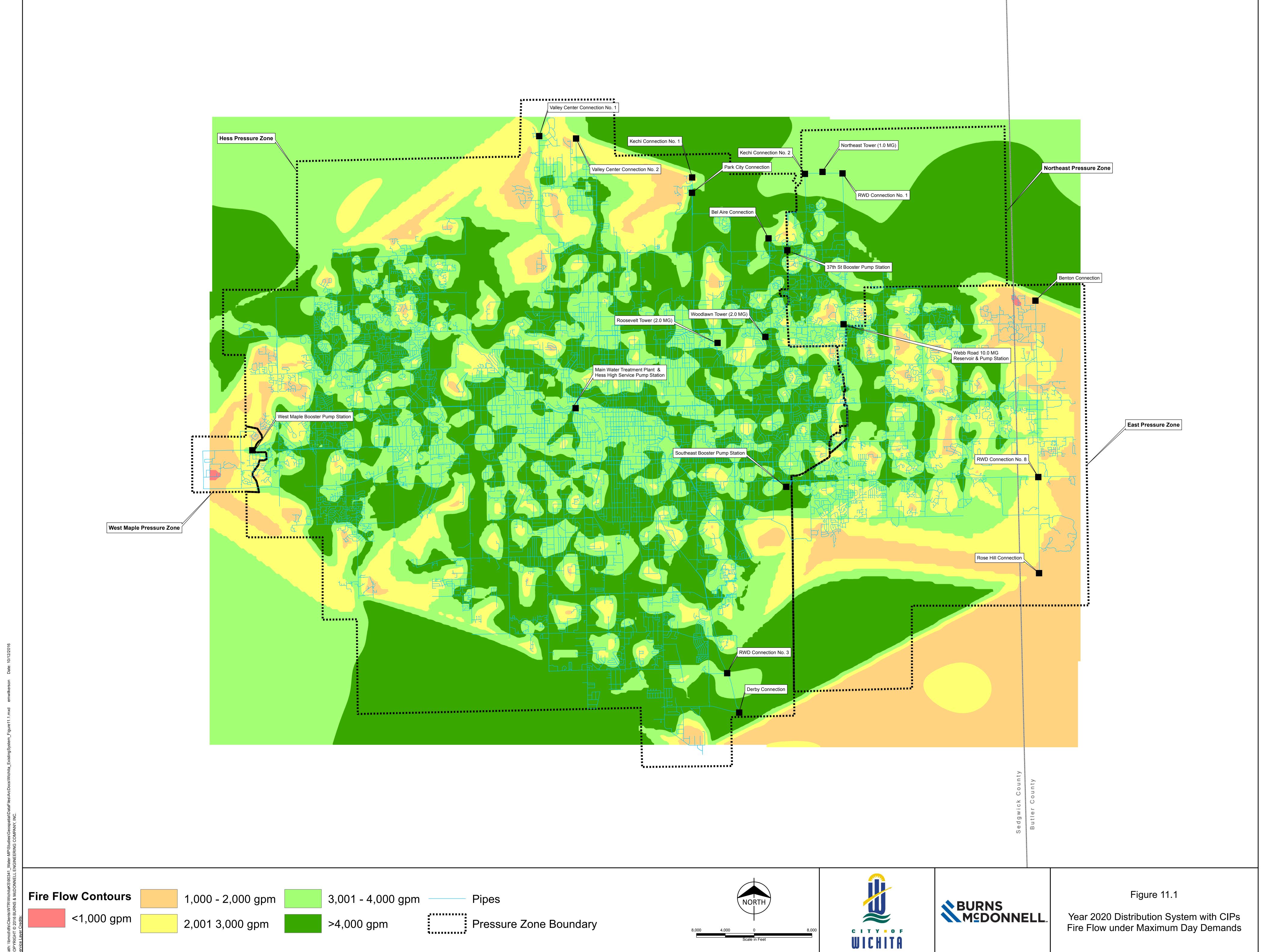
• 2020-Hess-F-11, 2020-Hess-F-13, and 2020-Hess-F-14: these 12-inch improvements total approximately 2.0 miles and primarily serve to increase fire flow; looping is an added benefit around Explorer Elementary School, Apollo Elementary School, Eisenhower Middle School, and Eisenhower High School. Fire hydrant testing should also be conducted during peak demand conditions when all schools are in session. The fire flow requirements may exceed typical residential needs of 1,000 gpm and should be determined by the fire marshal or the governing authority. If the fire flow test results are adequate, then these improvements are not required until future development occurs in these areas. If the fire hydrant testing is inadequate and the proposed lines are needed to meet the fire flow requirement, then the City should consider implementing automatic flushing devices on hydrants connected to this loop to maintain water quality and decrease water age. The model results indicate very little to no flow in these improvements under maximum day and peak hour demand conditions.

Other projects identified in the fire flow analysis that are recommended but not funded by the City are listed below. For clarity, these improvements are included in the model. These projects are anticipated to be initiated by the developer and funded by Special Assessments or Private Projects improvements as indicated by City staff:

- PIPE781 includes approximately 1,060 feet of 8-inch diameter pipe extending from the existing 8-inch dead end on Forestview Street to the existing 8-inch dead end on W Harvest Lane.
- PIPE783 includes approximately 3,640 feet of 8-inch diameter pipe extending from the existing 8-inch dead end on Flint Hills National Parkway near SW 120th Street to the existing 8-inch dead end near the intersection of Flint Hills National Parkway and E Quail Ridge Court.
- PIPE779 includes approximately 1,880 feet of 12-inch diameter pipe extending east from S 151st
 Street W to the existing 8-inch dead end on N Fawnwood Street; note, this improvement requires implementing and accelerating CIP 2045-Hess-G-65.

11.2 Year 2035 Planning Period

The water demand projections and corresponding demand conditions for the year 2035 planning period are listed below and require approximately 1.2 miles of linear hydraulic related improvements and pumping improvements at two BPS to support infill growth within the City's existing water service area.



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The hydraulic and fire flow related improvements recommended in the 2020 planning period are adequate for the fire flow needs of the 2035 planning period; therefore, there are no fire flow related improvements.

- Maximum Day = 127 MGD
- Peak Hour = 171 MGD
- Minimum Hour = 62 MGD

11.2.1 Pumping and Pressure

Pumping improvements required to meet the projected water demands include one pump at West Maple BPS and one pump at Southeast BPS. The West Maple BPS pump should be sized to match the existing pumps at 537 gpm at 111 feet of pump head. The additional flow required in this planning period is the result of expanding the West Maple pressure zone to include the area bound by Kellogg Avenue, South 135th Street West, and West Maple Street. The West Maple pressure zone expansion into the periphery of Hess pressure zone is relatively minor geographically, but it increases the pressure above 40 psi.

The Southeast BPS pump can be sized to deliver 24 MGD at 130 feet of pump head which will increase the firm capacity of the BPS to 24 MGD as designed. The smaller pump(s) at Southeast BPS are utilized under maximum day and peak hour demand conditions to supplement East pressure zone flow from Webb Road PS. Other pumps sizes, with respect to flow and head, can be evaluated if it provides more operational flexibility and increases BPS usage, but efforts to reincorporate this BPS with the smaller pumps should be done first to determine its ability and/or inabilities since the demand conditions it was designed for have changed extensively. All other pump stations have adequate pumping capacity to deliver the peak hour and maximum day plus fire flow demand conditions.

Distribution system pressure is greater than 40 psi. Flow and pressure contributions from each pump station and pressure control points in the distribution system are summarized in Tables 11.5 and 11.6. The model results for pressure under maximum day and peak hour demand conditions are near acceptable levels to current desired range; note, operational changes associated with the Northeast pressure zone and Northeast Tower are in effect and usage of the Southeast BPS for the East Pressure zone is included in these future system model scenarios, therefore, the existing operating pressure ranges may not apply for comparison purposes under these conditions.

11.2.2 Storage

The storage analysis methodology discussed in Section 6.0 is applied for the 2035 planning period and is based on the maximum day demand and minimum storage requirement for fire and equalization. Results

Table 11.5
Year 2035 Pumping and Pressure Results

	Eviating Desired	Maximum Day		Peak Hour		
Pump Station	Pressure Zone	Existing Desired Range (psi)	Flow (MGD)	Pressure (psi)	Flow (MGD)	Pressure (psi)
Hess HSPS	Hess	98-103	116.2	98	154.9	99
Webb Road PS	Northeast	65-85	10.8	87	11.1	86
37th St BPS	Northeast	note 1	0.0	83	1.2	82
Webb Road PS	East	55-65	8.5	76	11.4	68
Southeast BPS	East	note 2	14.6	113	19.8	114
West Maple BPS	West Maple	75-80	1.0	80	1.3	83

- 1. 37th St BPS flow is utilized in a supplemental operation to Webb Rd PS; there is no desired disharge pressure range.
- 2. Southeast BPS has been not been utilized by the City; there is no desired discharge pressure range.

Table 11.6
Year 2035 Distribution System Pressure Results

		Evisting Dosired	Maximum Day	Peak Hour
Pump Station	Pressure Zone	Existing Desired Range (psi)	Pressure (psi)	Pressure (psi)
Central & Main	Hess	92	91	91
Kellogg & Webb	Northeast	50-60	87	83
Harry & Webb	East	55-65	60	58
Maple & 167th	West Maple	55-60	64	65

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of the storage analysis are listed in Tables 11.7 and 11.8 and indicate a storage surplus of 9.0 MG for the Hess, East, and West Maple pressure zones and a storage surplus of 5.5 MG for the Northeast pressure zone; no additional storage is required in the distribution system.

Under minimum hour demand conditions and/or low flow periods at night, lasting 4 to 5 hours, the distribution system and Hess HSPS is capable of filling Webb Road reservoir, Woodlawn Tower, and Roosevelt Tower. Additionally, the distribution system and new pumps at Webb Road PS serving the Northeast pressure zone have adequate capacity to fill the Northeast Tower during low demand periods.

11.2.3 Distribution System Hydraulics

There are ten capital improvements with hydraulic triggers to support the year 2035 demand projection and infill growth; nine of them these are smaller projects, each less than 200 ft in length and are attributed to undersized parallel water mains that exhibit velocity greater than 5 fps and headloss greater than 6 ft per 1,000 ft. The headloss is manageable and does not impact distribution system hydraulics greatly, but higher velocities can result in water main breaks during periods of accelerated flows through the system such as fire flow. The larger projects include the following:

 2035-Hess-H-8: approximately 3,800 feet of 16-inch pipe is required to convey flows into the southwestern parts of Hess pressure zone and west of Interstate 235. This improvement parallels the existing 20-inch water main on West Maple Street from South Ralstin Road to Woodchuck Street.

11.3 Year 2045 Planning Period

The existing distribution system and the capital improvements recommended in the 2020 and 2035 planning periods are adequate to support the water demand projections for the year 2045. The water demand projections and corresponding demand conditions for the year 2045 planning period are listed below and require approximately 77.6 miles of linear development driven improvements to support infill growth and peripheral growth beyond the City's existing water service area.

- Maximum Day = 128 MGD
- Peak Hour = 175 MGD
- Minimum Hour = 63 MGD

The hydraulic and fire flow related improvements recommended in the 2020 and 2035 planning period are adequate for the fire flow needs of the 2045 planning period; therefore, there are no fire flow related improvements. Furthermore, the distribution system does not require any pumping or storage

Table 11.7
Year 2035 Storage Analysis: Northeast Pressure Zone

Item	Amount based on Effective Storage ¹	Amount based on Total Storage ²
Fire or Emergency Demand (gpm)	3,500	same
Duration (hours)	3.0	same
Fire or Emergency Volume (MG)	0.6	same
Equalizing Factor (MG/MGD)	0.12	same
2035 Maximum Day Demand (MG)	10.8	same
Equalizing Volume (MG)	1.3	same
Total Storage Volume Required (MG)	2.0	same
Effective ¹ or Total ² Storage (MG)	7.5	11.0
Storage Surplus (MG)	5.5	9.0

- 1. Effective storage = 6.5 MG from Webb Reservoir and 1.0 MG from Northeast Tower; 6.5 MG from Webb Reservoir represents volume of water above 7.0 ft.
- 2. Total storage = 10.0 MGD from Webb Reservoir and 1.0 from Northeast Tower.

Table 11.8
Year 2035 Storage Analysis: Hess, East, and
West Maple Pressure Zones

ltem	Amount based on Effective Storage ¹	Amount based on Total Storage ²
Fire or Emergency Demand (gpm)	7,000	same
Duration (hours)	4.0	same
Fire or Emergency Volume (MG)	1.7	same
Equalizing Factor (MG/MGD)	0.13	same
2035 Maximum Day Demand (MG)	115.7	same
Equalizing Volume (MG)	15.0	same
Total Storage Volume Required (MG)	16.7	same
Effective ¹ or Total ² Storage (MG)	25.7	35.1
Storage Surplus (MG)	9.0	18.4

Notes:

- 1. Effective storage = considered the volume above 4 ft in Hess reservoir system and assumes pumps are on above a water level of 7 ft.
- 2. Total storage = 35.1 MG from Hess reservoirs.

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improvements. While the water service area does expand beyond the existing limits in year 2045, there is only marginal increase in the water demand projections compared to the year 2035 of about 1 MGD for maximum day.

Water main projects totaling 12 miles to support future growth in Andover is included in the model, but are not represented as capital improvements in the CIP. These projects are anticipated to be initiated by the developer and funded by Special Assessments or Private Projects improvements as indicated by City staff.

11.3.1 Pumping and Pressure

West Maple pressure zone expands north into future development areas between North 167th Street West and North 151st Street West, and south of West 13th Street North. West Maple pressure zone also extends south between South 151st Street West and South 135th Street West to West 23rd Street South. Flow and pressure contributions from each pump station and pressure control points in the distribution system are summarized in Tables 11.9 and 11.10. The model results for pressure under maximum day and peak hour demand conditions are near acceptable levels to current desired range; note, operational changes associated with the Northeast pressure zone and Northeast Tower are in effect and usage of the Southeast BPS for the East Pressure zone is included in these future system model scenarios, therefore, the existing operating pressure ranges may not apply for comparison purposes under these conditions.

11.3.2 Storage

The storage analysis methodology discussed in Section 6.0 is applied for the 2045 planning period and is based on the maximum day demand and minimum storage requirement for fire and equalization. Results of the storage analysis are listed in Tables 11.11 and 11.12 and indicates a storage surplus of 8.8 MG for the Hess, East, and West Maple pressure zones and a storage surplus of 5.5 MG for the Northeast pressure zone; no additional storage is required in the distribution system.

Under minimum hour demand conditions and/or low flow periods at night, lasting 4 to 5 hours, the distribution system and Hess HSPS is capable of filling Webb Road reservoir, Woodlawn Tower, and Roosevelt Tower. Additionally, the distribution system and new pumps at Webb Road PS serving the Northeast pressure zone have adequate capacity to fill the Northeast Tower during low demand periods.

11.4 NWTP Option 2 Distribution System Improvements

All improvements discussed previously in this Section represent the Base Option for the distribution system. Option No. 1 includes the new NWTP in the year 2035 planning period, but has dedicated treated

Table 11.9
Year 2045 Pumping and Pressure Results

	Eviating Desired	Maximum Day		Peak Hour		
Pump Station	Pressure Zone	Existing Desired Range (psi)	Flow (MGD)	Pressure (psi)	Flow (MGD)	Pressure (psi)
Hess HSPS	Hess	98-103	119.8	99	158.7	100
Webb Road PS	Northeast	65-85	10.8	87	11.1	86
37th St BPS	Northeast	note 1	0.0	83	1.2	82
Webb Road PS	East	55-65	10.0	77	12.5	65
Southeast BPS	East	note 2	15.4	113	21.0	111
West Maple BPS	West Maple	75-80	1.2	82	1.6	69

- 1. 37th St BPS flow is utilized in a supplemental operation to Webb Rd PS; there is no desired disharge pressure range.
- 2. Southeast BPS has been not been utilized by the City; there is no desired discharge pressure range.

Table 11.10
Year 2045 Distribution System Pressure Results

		Evisting Dosired	Maximum Day	Peak Hour
Pump Station	Pressure Zone	Existing Desired Range (psi)	Pressure (psi)	Pressure (psi)
Central & Main	Hess	92	92	91
Kellogg & Webb	Northeast	50-60	60	58
Harry & Webb	East	55-65	89	80
Maple & 167th	West Maple	55-60	64	51

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Table 11.11
Year 2045 Storage Analysis: Northeast Pressure Zone

Item	Amount based on Effective Storage ¹	Amount based on Total Storage ²
Fire or Emergency Demand (gpm)	3,500	same
Duration (hours)	3.0	same
Fire or Emergency Volume (MG)	0.6	same
Equalizing Factor (MG/MGD)	0.12	same
2045 Maximum Day Demand (MG)	10.8	same
Equalizing Volume (MG)	1.3	same
Total Storage Volume Required (MG)	2.0	same
Effective ¹ or Total ² Storage (MG)	7.5	11.0
Storage Surplus (MG)	5.5	9.0

- 1. Effective storage = 6.5 MG from Webb Reservoir and 1.0 MG from Northeast Tower; 6.5 MG from Webb Reservoir represents volume of water above 7.0 ft.
- 2. Total storage = 10.0 MGD from Webb Reservoir and 1.0 from Northeast Tower.

Table 11.12
Year 2045 Storage Analysis: Hess, East, and
West Maple Pressure Zones

Item	Amount based on Effective Storage ¹	Amount based on Total Storage ²
Fire or Emergency Demand (gpm)	7,000	same
Duration (hours)	4.0	same
Fire or Emergency Volume (MG)	1.7	same
Equalizing Factor (MG/MGD)	0.13	same
2045 Maximum Day Demand (MG)	117.2	same
Equalizing Volume (MG)	15.2	same
Total Storage Volume Required (MG)	16.9	same
Effective ¹ or Total ² Storage (MG)	25.7	35.1
Storage Surplus (MG)	8.8	18.2

Notes:

- 1. Effective storage = considered the volume above 4 ft in Hess reservoir system and assumes pumps are on above a water level of 7 ft.
- 2. Total storage = 35.1 MG from Hess reservoirs.

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water transmission to Hess reservoir system where it is pumped to the distribution system via Hess HSPS; therefore, there are no capital improvements in the distribution system required to support Option No. 1.

Option No. 2 is similar to Option No. 1 with respect to the new NWTP located at 21st and Zoo Boulevard except that treated water is delivered directly to the distribution system. Option No. 2 requires approximately 3.1 miles of 66-inch transmission in the distribution system to deliver 80 MGD from the new NWTP. This transmission main (CIP designation 2035-Hess-Option 2-H-1) parallels the existing 36-inch water main from 21st and Zoo Boulevard southwest and ties into the existing 48-inch transmission main near the intersection of North McLean Boulevard and Central Avenue.

Assuming a grade elevation of approximately 1,323 ft at the NWTP, the hydraulic gradient needed to deliver 80 MGD is approximately 1,528 ft under the maximum day demand. This matches the hydraulic gradient of the 2035 and 2045 planning period results for the Base Option (without the NWTP). The parallel 66-inch transmission main improvement discussed in the previous paragraph is required to maintain this hydraulic gradient.

11.5 Northeast Pressure Zone Operation with Northeast Tower

When the Northeast Tower is placed in service, the Northeast pressure zone will transition from a closed system to an open system and require changes to the operational controls at Webb Road PS. The current mode of operation at Webb Road PS utilizes the VFDs to maintain a constant discharge pressure and/or pressure range at 34th Street and Webb Road under varying rates of flow and utilizes 37th Street BPS in a supplementary role for flow support. When the Northeast Tower is placed in service, the Webb Rd PS pumps should be run at constant speed or constant reduced speed and cycle on and off based on operator pre-set levels in the Northeast Tower.

In open distribution systems, pump stations are commonly sized to deliver maximum day demands and rely on elevated storage to provide peaking demands, or equalization demands, and storage for fire. Equalization storage is typically considered the upper portion of elevated tanks and fire protection is the bottom portion. However, equalization storage for the Northeast pressure zone will be provided by a combination of Webb reservoir and the Northeast Tower and is discussed in further detail at the end of this section.

Model results during peak hour demands of approximately 10.8 MGD indicate a drafting rate of approximately 1,400 gpm from Northeast Tower and is equivalent to a volume 84,000 gallons. The storage volume for equalization also represents approximately 3.5 ft within the 40 ft head range of the

Northeast Tower. The fire flow requirement is 3,500 gpm for 3 hours and is equivalent to 630,000 gallons. The storage volume for fire represents approximately 25 ft within the 40 ft head range of the tower.

Establishing operational controls for Webb Road PS to interact with the Northeast Tower also must consider tank turnover in addition to the fire protection and equalization storage needs of the pressure zone as well. The recommended tank turnover to maintain water quality and prevent high water age ranges from 25 percent to 33 percent of the total volume daily. Applying the low-end turnover recommendation of 25 percent represents 10 ft within the 40 ft head range of the tower.

Based on the equalization demands, fire storage needs, and recommended turnover volume of the Northeast Tower, the control points for Webb Road PS are listed below:

- Maintain a minimum water level of 25 ft in the tower for fire protection;
- Pump or pumps on at 26 ft (depending on how fast staff wants to/can fill the tower, two pumps can by cycled on concurrently, this maybe a seasonal adjustment); and
- Pump or Pumps off at 36 ft.

The pumps can also be operated in a lead-lag manner to mitigate excessive drafting rates, greater than 1,500 gpm) from the Northeast Tower or additional pumps can be cycled on at 37th Street BPS if adequate information on the pump curves can be developed from pump testing. If the existing 37th Street BPS pumps cannot support Northeast pressure zone hydraulics with the new pumps at Webb Road PS and the Northeast Tower in service, then pump replacement should be considered. For clarity, these are recommended starting points and should be adjusted for current demand conditions. The pump speed at Webb Road PS can be full speed or a constant reduced speed. To determine a recommended pump speed initially (startup testing), operators can start at lower speeds, 70 percent for example, and increase the speed until drafting rates in the tower do not exceed 1,000 gpm during peak hour conditions and are still able to fill the tower at night or during low demand periods. Note, pump speeds may need to be adjusted seasonally because base demands experienced during peak summer months may require the full amount of storage in the tower and during low demand seasons, like winter, the tower may not require as much storage.

Other impacts in the distribution system stemming from the Northeast Tower may alter normal, or current, operating levels in Webb reservoir. Webb reservoir serves multiple purposes and one of its more important functions is a buffering mechanism that allows operators to bleed off pressure in Hess pressure

zone if they exceed 92 psi at Central and Main or bleed of excess flow if the Woodlawn or Roosevelt towers are nearly full. Since the Northeast Tower will serve as the supply mechanism for equalization demands and Webb reservoir will no longer need to, the operating range of the reservoir may need to be lowered to continue serving as a buffering mechanism.

In conclusion, peaking demands are provided by the Northeast Tower; therefore, Webb reservoir storage turnover will decrease and potentially limit its ability to receive water from Hess pressure zone; to combat this, the operating range of Webb reservoir should be adjusted concurrently as the Northeast Tower is placed in service. In which case, the storage evaluation for the Northeast pressure zone in Section 6.0 identifies what the reservoir levels can be lowered to (with consideration to the City's desired emergency storage volume at Webb reservoir). Based on the storage analysis presented in Table 11.3, Webb reservoir needs to provide approximately 0.83 MG of storage for equalization for the year 2020 maximum day demand of 9.8 MGD.

11.6 Southeast BPS Control

As indicated previously in Section 6.0, City staff and WTP operators reported difficulties operating the Southeast BPS. These are potentially caused by recycling water back into Hess pressure zone as illustrated by the minimal increase in discharge pressure when the BPS was in service. An open pressure zone boundary valve, or multiple valves that should normally be closed to isolate the Hess and East pressure zones, or closed suction/discharge valves are potential causes.

The Southeast BPS was designed to address low pressures south of Kellogg and Webb and in neighboring areas west of this intersection in the Hess pressure zone, meet the projected and expansive growth in the East pressure zone, and transfer of customers from the Hess pressure zone through a western expansion of the East pressure zone. Future growth that was expected to occur beyond the northern and southern limits of the existing distribution system has been marginal. For perspective, the year 2020 planning period is common in the 2003 Water Master Plan and this master plan; a comparison of the demand conditions for the East pressure zone is listed in Table 11.13 below. Review of the demand projections show a 48 percent reduction of the maximum day demand and a 62 percent reduction of the peak hour demand from in 2003 Water Master Plan projections for the year 2020.

Table 11.13 - East Pressure Zone Demand Projections

Water Master Plan	Planning Period	Maximum Day (MGD)	Peak Hour (MGD)
2016	2020	19.3	24.5
2003	2020	36.8	63.5

In 2003 the average and maximum day demands in the East pressure zone were estimated at 6.1 MGD and 11.5 MGD respectively. Demands in the East pressure zone have remained consistent and in 2015 the maximum day demand was less than that experienced in 2003; in 2015 the average and maximum day demands are estimated at approximately 7.2 MGD and 11.3 MGD.

The Southeast BPS is integrated in the maximum day and peak hour demand conditions of the 2020, 2035, and 2045 planning periods of the model to determine its service potential since the future growth plan and demand projections have changed significantly over the last 10 years. The model results validate its service potential and integrating the Southeast BPS back into the City's operations is recommended. However, based on the demand projections, its use is likely limited to peak hour conditions during high seasonal demand periods, and its service is expected to increase as water demands increase in the East pressure zone. A brief description of the integrated control features between Webb Road PS and Southeast BPS that the system was designed around, and should still be applicable, is listed below:

- Webb Road PS and Southeast BPS operate as a single pump station with a control system that
 automatically starts and stops pumps to maintain pressure in the East pressure zone; the pressure
 control point is the discharge header of Southeast BPS.
- Under low demand conditions when pressure is between 60 psi and 80 psi and all pumps (Webb Road PS and Southeast BPS), the bypass valves at both pump stations are open.
- If pressure drops below 60 psi, the bypass valve at Webb Road PS will close and the lead pump at Webb Road PS will start and utilize the VFD controlled by the PID loop programmed at Webb Road PS to maintain a pressure of 70 psi.
- If pressure drops below 60 psi, the bypass valve at Southeast BPS will close and the lead pump at Southeast BPS will start (constant speed) and the PID loop will control the VFD to maintain a discharge pressure of 100 psi.
- If pressure drops below 90 psi, the lag pump at Webb Road PS will start (constant speed) and the PID loop will control the VFDs of both pumps to maintain a pressure of 100 psi.
- If pressure rises above 110 psi, the lead pump at Webb Road PS will stop. The PID loop will control the VFD to maintain a pressure of 100 psi.
- If pressure rises above 110 psi, the lag pump at Webb Road PS will stop. The PID loop will control the VFD to maintain a pressure of 100 psi.
- If pressure rises above 110 psi, the lead pump at Webb Road PS will start and the bypass valve will close. The lead pump at Southeast BPS will stop and the bypass valve will open. The

pressure set point will change from 100 psi to 70 psi; the PID loop will control the VFD to maintain a pressure of 70 psi.

• If pressure rises above 80 psi or the Webb Road PS flow rate falls to 5.8 MGD, the lead pump at Webb Road PS will close and the bypass is signaled to open.

* * * * *

12.0 CONSERVATION EFFORTS

This section of the report discusses the City's current water conservation efforts and recommendations for effective strategies that can reduce the average day demand and mitigate peak demands. Water conservation strategies also reduce water waste in the short-term and enhance water supply reliability in the long-term. Each conservation practice can have varying implications on average day and peak demand conditions, as well as customer benefits, such as:

- Lowering the average day demand decreases distribution system storage needs and reduces peak
 demands which can eliminate, reduce size, or delay capital improvements for additional supply,
 additional treatment capacity, new distribution system infrastructure, and lower O&M costs;
- Improving existing technologies, such as indoor plumbing fixtures, can reduce annual average demand, but will not affect summer peak demand;
- Xeriscape and the use of drought tolerant grasses reduces outdoor irrigation needs and reduces peak demands during the summer months;
- Seasonal pricing strategy for landscaping can combat high summer peak demands; and
- Customers benefit from conservation measures through lower water and sewer costs.

12.1 City Conservation Programs

In 1991 the City adopted its first Water Management and Conservation Plan and has been the driving force for water conservation. Many of the water conservation measures discussed above have been implemented in some form by the City and include the following:

- Annual conservation goal of 0.35 percent.
- Water measurement and accounting: metering all source water and treated water components for normal consumption activity. The City has undergone a distribution system-wide meter replacement program with automatic meter reading technology; accurate customer billing is pivotal in lowering apparent losses, as defined by AWWA M36, and represents revenue that can be recovered and valued at the customer retail unit rate;
- Water pricing structure: an inclining block rate structure was implemented in 1993 for customers
 within City limits and additional charges on top of the rate structure for those outside City limits.
 Additionally, a flat water rate is available for large seasonal customers willing to reduce their
 consumption by 20 percent or 4 acre-feet, whichever is larger, and are assessed monetary fees if
 water usage is above the contracted amount;

 Rebate program from 2013 to 2016 for high efficient appliances including cloth washers, dishwashers, dual flush converter kits, irrigation smart controllers, low flow urinals, rain sensor shutoff, rain barrels, and toilets;

- Public education and awareness: the City's website offers guidance and information to save water on the customer end such as lawn watering recommendations, irrigation measures that conserve water, lawn care information, pool care, and links to a variety of other resources in this topic area. The website also informs customers on the City's internal conservation plans and supply management, most notably the Aquifer Storage and Recovery Project and efforts related to protecting Cheney Reservoir. The City conducted over 60 programs in 2016 at the WATER Center including presentations on water conservation;
 - WATER Center staff prepares water system characterization reports, reviews
 conservation plans, reviews retail volume applications and annual usage for compliance
 for retail volume contracts, and oversees the annual rebate program to name a few;
- The City has held a designated water efficiency coordinator position since 1990.
- Ongoing small mains replacement, particularly 2-inch galvanized pipe;
- Adopted a Drought/Water Shortage Contingency Plan that includes implementing voluntary and mandatory water efficiency measures;
- Wastewater reuse for the City's largest water user is anticipating a reduction in potable water consumption of 40 percent in 2017 and 70 percent in 2018 and beyond;
- Conjunctive use for the City's raw water supply sources; and
- Wholesale customer contracts include provisions to implement water efficiency plans that are, at a minimum, as comprehensive as the City's.

The City is also recommitting to the Kansas Water Office (KWO) guidelines, which is also supported by the Bureau of Reclamation and the Environmental Protection Agency, in areas of education efficiency practices, management efficiency practices, and regulatory efficiency practices.

The American Water Works Associations (AWWA) published a technical manual, M52 – Water Conservation Programs, detailing recommendations for conservation principles and practices in the municipal water industry. The City's conservation efforts are very comprehensive and include, in some form or fashion, those recommended by AWWA. Of note, the KWO guidelines discussed above are referenced in the AWWA M52 as exemplary practices for water conservation. A summary of the AWWA recommendations is listed below, and again, the City has or is currently performing all of these efforts in some form:

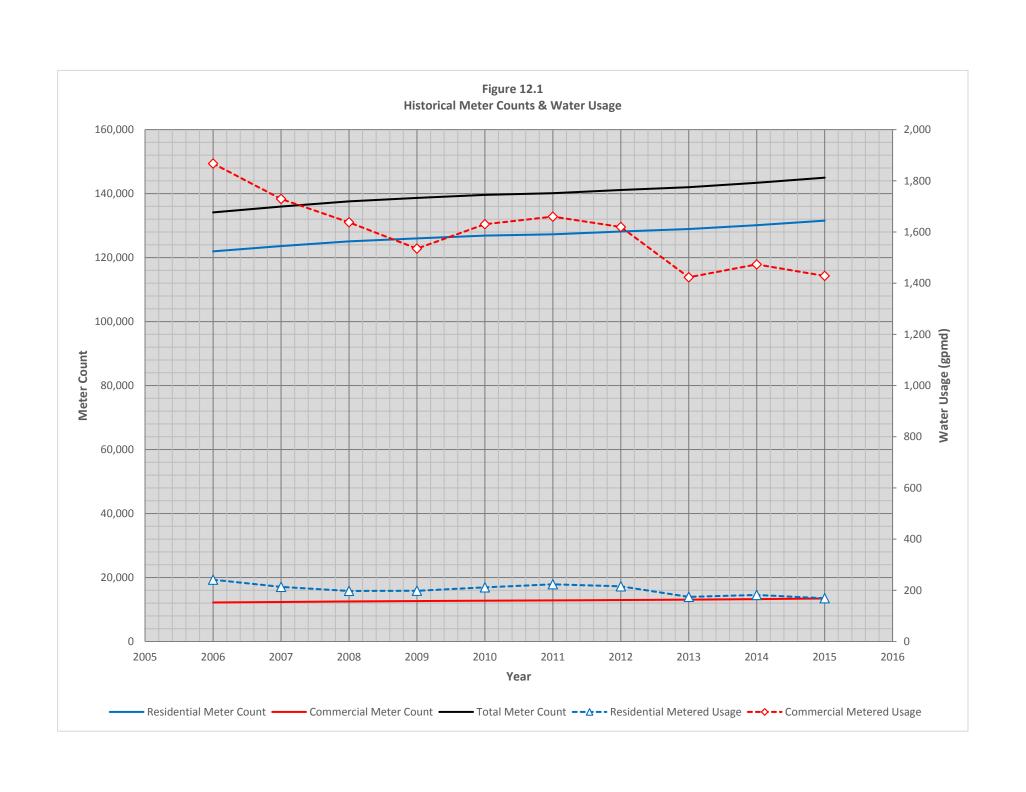
- Efficient utilization of supply sources;
- Integrated resource planning;
- Leak detection;
- Asset rehabilitation and replacement;
- Consumption monitoring with meter usage;
- Customer pricing tiered block rate structure;
- Public awareness and education; and
- Reuse water/wastewater.

12.2 Conservation Impacts: Nonrevenue Water and Customer Usage

The traditional method for determining the City's nonrevenue water status on an annual basis is the difference between that average day demand (based on WTP flow metering) and the metered customer consumption from the City's billing system. Since 2006, nonrevenue water levels ranged from 9 percent to 16 percent, with an average of 12 percent. These are good nonrevenue metrics for a water utility of Wichita's size, by traditional estimations. However, traditional definitions for nonrevenue and its estimation can vary greatly throughout the industry, therefore, caution must be given when characterizing the City's water loss standing or drawing any further conclusions on this metric alone.

Utilities with AMR technology in place provide enhanced metering accuracy for customer consumption profiles and better data collection from the billing system – both of which provide a more reliable account of the City's nonrevenue and/or water loss standing in the distribution system. The system-wide meter replacement program that began in the late 1990's is nearly complete, having installed approximately 136,000 meters of the 150,000 active meters and 156,000 meters total (active and inactive). New meters with AMR capability and encoder receiver transmitters are replacing old meters; AMR is also required for all new construction/service connections. Though the presence of AMR technology in the City's system bolsters confidence in the traditional determination for nonrevenue water, it does not quantify or distinguish real losses in the distribution system or apparent losses in the meter/billing system.

The impact of the City's water conservation programs, to some extent, are reflected in the nonrevenue levels in addition to declinations in water usage during periods with escalating meter installations. These periods represent a better overall efficient use of water by customers and improved delivery and accounting mechanisms on behalf of the City and is illustrated in Figure 12.1. Water conservation programs can positively impact nonrevenue water and customer usage, but are not always the sole contributor. Wet weather, drought periods, and dry years are also factors impacting water usage. For



example, the last five years began with two years of relatively dry weather resulting in higher average day demands followed by almost two to three years of above average rainfall during summer months when peak hour demands are at their highest. Nonetheless, active meter installations continued to increase while customer consumption continued to decrease and are directly related to a combination of conservation efforts and weather.

12.3 Recommendations

The City has a solid water conservation program in place; however, there are several strategies that can be implemented over the next five years to evolve and enhance their current practices. Water conservation efforts recommended for the City, with the objective to reduce the average day demand and peak hour demands, includes the following in order of execution:

- Distribution system pressure management: evaluate and determine sub-pressure zone delineation potential to lower system pressure;
- AWWA M36 water audit: complete an annual water audit for the entire distribution system, for
 each pressure zone, and for each sub-pressure zone (if developed). This effort can be completed
 concurrently with distribution system pressure management tactics;
- Develop a leak detection program and response tactics for sub-pressure zone delineations.

12.3.1 Pressure Management

Water pressure has a direct relationship with leakage – lowering water pressure will lower distribution system leakage, thereby providing a means to lower baseline water demands. Managing distribution system water pressure not only minimizes the rate of leakage, it can also lower stress on pipe joints and extend the overall life of the City's distribution system and customer systems downstream of the service connection/meter assembly. The 2015 Uniform Plumbing Code requires pressure regulator valves where the static water pressure exceeds 80 psi for buildings and is also recommended for residential areas.

From a distribution system perspective, new pressure zones that do not require booster pumping should be considered to lower system pressure. Pressure zones that do not require booster pumping are delineated as sub-pressure zones that have an abundance of pressure. Pressure reducing valves are installed on adequately sized water mains for water supply to the sub-pressure zone. Sub-pressure zone boundaries are created by closing valves to isolate the area, very similar to the City's current pressure zone boundaries except that check valves cannot be used. Each of the pressure zones and sub-pressure zones should be metered to help identify, track, and correct water loss in these areas if the data/flow analyses are conclusive enough.

Based on the pressure density map illustrated in Figure 6.7, there is potential for sub-pressure zone formation in southern parts of the Hess pressure zone and southeastern parts of the East pressure zone. These areas have an abundance of pressure largely in part due to their topography which includes the lower elevations within the distribution system. Sub-pressure zones should be delineated based on topography and evaluated with the hydraulic model to identify pressure reducing valve locations, confirm adequate water main sizing for customer demands, evaluate fire protection needs, and confirm the City's existing distribution system control measures can be upheld or improved.

12.3.2 Water Auditing

A standardized method was developed by AWWA and the International Water Association (IWA) to identify inefficiencies in the water distribution system and is detailed in the Water Audits and Loss Control Programs Technical Manual M36. The auditing begins with a top-down approach characterized as an initial desktop analysis to quantify real loss volumes and system performance based on the water balance method. The City has naturally defined areas for auditing purposes from the pressure zones in the distribution system. Therefore, a water balance and AWWA M36 water audit is recommended for the entire system and for each pressure zone (top-down approach) and sub-pressure zones if implemented for pressure management as discussed in the previous paragraph. Conducting water audits by pressure zone will provide guidance where more or less focus for bottom-up approaches should be given. The top-down approach helps in determining if bottom-up approaches, such as DMAs, are justifiable based on the level of unavoidable annual real losses; this value represents the theoretical low limit of leakage that could be achieved if all of today's best technology were successfully applied.

An AWWA M36 water audit quantifies the type and amount of nonrevenue water, authorized or otherwise, occurring in the distribution system and begins with a water balance. The water balance tracks water from the treatment process to the end users as shown in Table 12.1. The results of the water audit also provide guidance where additional conservation efforts should be focused, benchmark scoring for comparisons with other utilities of similar size (also known as the Infrastructure Leakage Index (ILI)), validity scoring, and other financial and operational performance indicators. A summary of the performance indicators provided by the water audit is listed in Table 12.2. Planning guidance for water loss control based on validity scoring and guidelines for ILI target setting are shown in Table 12.3.

The AWWA M36 water audit separates water loss into real losses and apparent losses. Real losses are physical losses that occur in the distribution system from pipe breaks, leaky fittings, or tank overflows in the distribution system. Apparent losses are "paper losses" stemming from inaccurate meter reporting, systematic data handling errors, and unauthorized consumption. Assessing the magnitude of these losses

		AW	/WA Free Wa	ter Audit Software: <u>Wat</u>	Americ	WAS v5.0 can Water Works Association. © 2014, All Rights Reserved.
		Wa	ater Audit Report for: Reporting Year: Data Validity Score:		ontact information on the Instructions tab >> * Confirm Units and Data Grading are Complete	9
		Water Exported 0.000			Billed Water Exported	Revenue Water 0.000
				Billed Authorized Consumption	Billed Metered Consumption (water exported is removed) 0.000	Revenue Water
Own Sources (Adjusted for known			Authorized Consumption	0.000	Billed Unmetered Consumption 0.000	0.000
errors)		0.000	0.000 Unbilled Authorized Consumption	Unbilled Metered Consumption 0.000	Non-Revenue Water (NRW)	
0.000				0.000	Unbilled Unmetered Consumption 0.000	
	System Input 0.000	Water Supplied		Apparent Losses 0.000	Unauthorized Consumption 0.000 Customer Metering Inaccuracies 0.000	0.000
			Water Losses		Systematic Data Handling Errors 0.000	
Water Imported 0.000			0.000	Real Losses 0.000	Leakage on Transmission and/or Distribution Mains Not broken down Leakage and Overflows at Utility's Storage Tanks Not broken down	
					Leakage on Service Connections Not broken down	

Table 12.2 IWA/AWWA M36 Water Audit Method - Performance Indicators

Function	Level ¹	Performance Indicator	Comments
Financial: Non-revenue Water by Volume	1, Basic	Volume of non-revenue water as a percentage of system input volume.	Easily calculated from the water balance, has limited value in high-level financial terms only; it is misleading to use this as a measure of operational efficiency.
Financial: Non-revenue Water by Cost	3, Detailed	Value of non-revenue water as a percentage of the annual cost of running the system.	Incorporates different unit costs for non-revenue components, good financial indicator.
Operational: Apparent Losses	1, Basic	[gal/service connection/day]	Basic but meaningful performance indicator for apparent losses. Can be calculated once apparent losses are quantified.
Operational: Real Losses	1, Basic	[gal/service connection/day], only if service connection density is less than 32/mi	Best of the simple "traditional" performance indicators, useful for target setting, limited use for comparisons between systems.
Operational: Real Losses	2, Intermediate	[gal/service connection/day]/psi, only if service connection density is less than 32/mi	Easy to calculate this indicator if the Infrastructure Leakage Index (ILI) is not yet known, useful for comparisons between systems.
Operational: Unavoidable Annual Real Losses (UARL) ¹	3, Detailed	UARL (gal) = (5.41L _m + 0.15N _c + 7.5L _c) x P	Theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. A key variable in the calculation of the ILI. The UARL calculation is not valid for systems with less than 3,000 service connections.
Operational: Real Losses	3, Detailed	ILI = CARL/UARL	Ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL); best indicator for comparisons between systems.

Notes:

City of Wichita, Kansas Burns and McDonnell

^{1.} L_m = length of mains (mi), N_c = number of service connections, L_c = total length of private service connections (mi) = N_c x average distance from curb stop to customer meters.

^{2.} Data from AWWA Technical Manual M36, Water Audits and Loss Control Programs.



AWWA Free Water Audit Software: Determining Water Loss Standing

WAS VS.

Water Audit Report for: << Please enter system details and contact information on the Instructions tab >> Reporting Year:

Data Validity Score: N/A* * Confirm Units and Data Grading are Complete

		Water Loss Cor	ntrol Planning Guid	le	
		Water A	Audit Data Validity Level	/ Score	
Functional Focus Area	Level I (0-25)	Level II (26-50)	Level III (51-70)	Level IV (71-90)	Level V (91-100)
Audit Data Collection	Launch auditing and loss control team; address production metering deficiencies	Analyze business process for customer metering and billing functions and water supply operations. Identify data gaps.	Establish/revise policies and procedures for data collection	Refine data collection practices and establish as routine business process	Annual water audit is a reliable gauge of year-to-year water efficiency standing
Short-term loss control	Research information on leak detection programs. Begin flowcharting analysis of customer billing system	Conduct loss assessment investigations on a sample portion of the system: customer meter testing, leak survey, unauthorized consumption, etc.	Establish ongoing mechanisms for customer meter accuracy testing, active leakage control and infrastructure monitoring	Refine, enhance or expand ongoing programs based upon economic justification	Stay abreast of improvements in metering, meter reading, billing, leakage management and infrastructure rehabilitation
Long-term loss control		Begin to assess long-term needs requiring large expenditure: customer meter replacement, water main replacement program, new customer billing system or Automatic Meter Reading (AMR) system.	Begin to assemble economic business case for long-term needs based upon improved data becoming available through the water audit process.	Conduct detailed planning, budgeting and launch of comprehensive improvements for metering, billing or infrastructure management	Continue incremental improvements in short-term and long-term loss control interventions
Target-setting			Establish long-term apparent and real loss reduction goals (+10 year horizon)	Establish mid-range (5 year horizon) apparent and real loss reduction goals	Evaluate and refine loss control goals on a yearly basis
Benchmarking			Preliminary Comparisons - can begin to rely upon the Infrastructure Leakage Index (ILI) for performance comparisons for real losses (see below table)	Performance Benchmarking - ILI is meaningful in comparing real loss standing	Identify Best Practices/ Best in class - the ILI is very reliable as a real loss performance indicator for best in class service

For validity scores of 50 or below, the shaded blocks should not be focus areas until better data validity is achieved.

Once data have been entered into the Reporting Worksheet, the performance indicators are automatically calculated. How does a water utility operator know how well his or her system is performing? The AWWA Water Loss Control Committee provided the following table to assist water utilities is gauging an approximate Infrastructure Leakage Index (ILI) that is appropriate for their water system and local conditions. The lower the amount of leakage and real losses that exist in the system, then the lower the ILI value will be.

<u>Note:</u> this table offers an approximate guideline for leakage reduction target-setting. The best means of setting such targets include performing an economic assessment of various loss control methods. However, this table is useful if such an assessment is not possible.

General Guidelines for Setting a Target ILI	
(without doing a full economic analysis of leakage control optio	ns)

	(without doing a rull eco	phomic analysis of leakage control	options)
Target ILI Range	Financial Considerations	Operational Considerations	Water Resources Considerations
1.0 - 3.0	Water resources are costly to develop or purchase; ability to increase revenues via water rates is greatly limited because of regulation or low ratepayer affordability.	Operating with system leakage above this level would require expansion of existing infrastructure and/or additional water resources to meet the demand.	Available resources are greatly limited and are very difficult and/or environmentally unsound to develop.
>3.0 -5.0	Water resources can be developed or purchased at reasonable expense; periodic water rate increases can be feasibly imposed and are tolerated by the customer population.	Existing water supply infrastructure capability is sufficient to meet long-term demand as long as reasonable leakage management controls are in place.	Water resources are believed to be sufficient to meet long-term needs, but demand management interventions (leakage management, water conservation) are included in the long-term
>5.0 - 8.0	Cost to purchase or obtain/treat water is low, as are rates charged to customers.	Superior reliability, capacity and integrity of the water supply infrastructure make it relatively immune to supply shortages.	Water resources are plentiful, reliable, and easily extracted.
Greater than 8.0		lay allow a long-term ILI greater than 8.0, such a leve 0 - other than as an incremental goal to a smaller lot	
Less than 1.0	levels in a class with the top worldwide performers in understated. This is likely if you calculate a low ILI	alue for your system is 1.0 or less, two possibilities on leakage control. b) A portion of your data may be value but do not employ extensive leakage control peasurements to confirm the accuracy of production a	flawed, causing your losses to be greatly ractices in your operations. In such cases it is

with a water audit can help the utility focus on recovering water supply for customers and increasing revenue (Green, 2010). Recovering apparent losses is typically addressed first because they are easier to identify and do not require the investment needed to address real losses in the distribution system which can be difficult and expensive to locate.

The bottom-up approach validates the results of the top-down approach with field measurements for target areas. Real loss components include three types of leakage: background leakage, unreported leakage, and reported leakage. The most accurate method to quantify these components is establishing DMAs in the distribution system to evaluate flow characteristics. DMA flow characteristics are evaluated by comparing metered water supply to the DMA with totalized customer usage from the City's AMR system. If DMAs are not a viable, then the pressure zones and potential sub-pressure zones can be relied on.

12.3.3 Leak Detection

Leak detection can be performed to decrease nonrevenue water (or real losses) especially if a water audit indicates significant water loss. Leak surveys can be conducted by several methods, with the use of acoustic technology being one of the most effective and common methods. Leaks caused by corroding or cracked pipes, installation issues, ground shifting, and several other reasons and can be detected using acoustic equipment. Once a leak is detected, pipe replacement, pipe linings, and point repairs can be made to repair leaks and eliminate any further water loss. Repairing leaking pipes can reduce average water demand throughout the year, not just peak demand (Green, 2010).

Traditional leak surveys involve manually sounding valves, fire hydrants, and other appurtenances along the piping system. Leak detection crews can perform ongoing surveys systematically throughout the distribution system. While traditional leak surveys may be systematic, they are not very sophisticated in terms of focused target areas of reported leakage and unreported leakage. Acoustic leak detection technology can be used to locate unreported leakage. While reported leaks are visible, background leakage is sonically undetectable. As part of a leak detection program, crews survey sections of the distributions system using acoustic equipment to listen for leaks through access of valves, hydrants, or other surface points. Then, sound waves are analyzed to determine the exact location of leaks.

A leak detection program can be developed alongside the creation of district metering areas (DMAs) and continuous flow monitoring. DMAs include continuous flow monitoring to quantify and control real losses occurring in the distribution system. DMAs are small service areas where the amount of flow leaked through cracked pipes or fittings, also called real losses and characterized as unreported leakage,

can be inferred from flow and metered consumption data. When a high minimum hour flow is recorded with flow monitoring equipment, the utility is notified and determines the appropriate response.

A program would allow the utility to locate a potential leak quickly and efficiently. Resources can be focused on areas with known leakage. If the City does not have adequate staffing to respond to unreported leakage or the maintenance and monitoring needs for DMA development, then in-line leak detection sensors can be implemented by companies specializing in leak detection with proprietary acoustic technology.

12.4 References

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13.0 EMERGENCY PREPAREDNESS

This section of the report discusses the City's emergency preparedness status for the water supply, treatment, and distribution systems. Specific areas of the water supply system evaluation include emergency power at Cheney PS and the EBWF, transmission redundancy, and additional supply sources; the water treatment system evaluation includes emergency power at the WTP and redundant treatment; and the distribution system evaluation includes emergency power at the pumping facilities, critical mains, and emergency storage.

13.1 Water Supply

13.1.1 Emergency Power

This section discusses backup power capabilities and plans for Cheney PS and the EBWF. Cheney PS has backup power capable of supporting three (3) pumps and the pre-treatment processes (copper and ozone systems) which is equivalent to a pumping capacity of 60 MGD based on the design point of each pump. The City has a plan ready project, Standby Power Generation to serve ASR Pump Stations (construction bids submitted December 2016, by others), for the EBWF that includes the addition of 22 generators at 22 production wells and one (1) portable generator. Assuming a production range of 600 gpm to 1,000 gpm per well, the total wellfield production capacity supported by emergency power generators ranges from 19 MGD to 32 MGD.

For the purposes of this evaluation, the emergency preparedness status compares the raw water supply capability under loss of power conditions in the EBWF and at Cheney PS individually. The EBWF production is based on a capacity test conducted by City staff in October 2016 at 55 MGD; assuming 10 percent of the wells are out of service for maintenance, the capacity is approximately 50 MGD. Sustainable production from Cheney PS is approximately 60 MGD as indicated by City staff. Therefore, a power failure in the EBWF (or at wells without backup power), results in a raw water supply range from 79 MGD to 92 MGD and a power failure at Cheney PS, results in a raw water supply of approximately 110 MGD with 10 percent of the wells out of service.

The raw water supply capability under the power failure conditions described above are compared to recent historical WTP production to quantify exceedance days and is illustrated in Figure 13.1. The period selected for comparison is from 2011 to 2016 and includes a mix of dry years (2011 and 2012) and wet years (2014 and 2015). Based on a power failure in the EBWF, there were a total of 152 days out of 2,190 days since 2011 where WTP production exceeded the low end of the raw water supply (79 MGD) and a total of 65 days where WTP production exceed the high end (92 MGD) of the raw water supply;



though it's important to note, that all of these days occurred during the dry years of 2011 and 2012. Regarding the sequencing or frequency of exceedance days, each occurred within 1 to 2 days of each other approximately 95 percent the time when WTP production was greater than 79 MGD. The current emergency preparedness status for a raw water supply of 110 MGD with a power failure at Cheney PS has exceeded daily WTP production since 2011; the maximum production over this period is 109 MGD and there were only 20 days since 2011 where WTP production exceeded 100 MGD.

With the implementation of the Standby Power Generation project, the emergency power status of the EBWF is better than it has ever been based on recent historical WTP production needs; furthermore, there is no groundwater contribution requirement for the treatment process. The City can elect to purchase more portable generators as part of the project if a higher level of protection, with respect to groundwater production under loss of power conditions, is desired for drought and dry weather conditions.

Implementing more permanent generator locations is not recommended because the production advantage on an individual well basis is outweighed by added maintenance and escalating age of an asset that may only be required only a few times per year. Furthermore, well production can degrade over time if well and pump maintenance is not upheld; therefore, additional backup power in the EBWF is better served by portable generators that would enable the City to mobilize at well locations with higher production rates. With respect to the Cheney system, as water use approaches the projected maximum day demand of 160 MGD, backup power to support a firm capacity of 80 MGD at Cheney pump station is recommended; however, this demand is currently projected to occur in 2060, which is beyond the 2045 planning period in this master plan.

13.1.2 Transmission Redundancy

As indicated previously in Section 8.0, EBWF production is conveyed to the WTP via a single 66-inch transmission main and Cheney PS production is conveyed to the WTP via 60-inch and 66-inch transmission mains (in series). The Cheney and EBWF transmission mains converge, but remain isolated near Station 187 valve vault, near 21st and Zoo Boulevard, then travel along different alignments (referred to as the northern and southern 66-inch alignments in Section 7.0) to the WTP. Currently there is no raw water transmission redundancy from Cheney PS to 21st and Zoo Boulevard; similarly, there is no transmission redundancy from the EBWF to 21st and Zoo Boulevard.

There is some degree of transmission redundancy from 21st and Zoo Boulevard to the WTP. The raw water model determined the capacity of the northern and southern 66-inch transmission mains if either is removed from service based on a minimum pressure of 25 psi (hydraulic grade line of 1,357 ft) at the

WTP. If the northern 66-inch transmission main is temporarily out of service and raw water is blended at Station 187, the maximum capacity of the southern 66-inch transmission main is approximately 125 MGD at a velocity of 8.1 fps. Similarly, if the southern 66-inch transmission main is temporarily out of service and raw water is blended at Station 187, the maximum capacity of the northern 66-inch transmission main is approximately 120 MGD at a velocity of 7.8 fps. These model results are based on full pipe flow conditions in the Cheney 60-inch transmission main, a static water level between 4 ft and 12 ft (Hydraulic Grade Line (HGL) between 1,518 ft and 1,526 ft) in Cheney surge tank, and a static water level between 48 ft and 56 ft (HGL between 1,441 ft and 1,449 ft) in the EBWF production surge tank.

Opinions of probable cost to provide full transmission redundancy are included in the capital improvements plan include the following:

- Cheney System
 - o Parallel 60-inch transmission main from Cheney PS to 21st and Zoo Boulevard.
- EBWF System
 - o Parallel 66-inch transmission from the EBWF to 21st and Zoo Boulevard.
- Raw Water System
 - Parallel 66-inch transmission from 21st and Zoo Boulevard to the WTP; with this improvement, a total of three (3) 66-inch transmission mains are available.

13.1.3 Additional Water Supply

City staff conducted a stress test of the EBWF in October 2016 and reported a maximum production capacity of 55 MGD; the 66-inch transmission main capacity was also tested between 75 MGD to 80 MGD using ASR treated water and the active storage volume of the production surge tank. An estimated 20 RRWs, with a minimum production capacity of 20 MGD and goal of 30 MGD, plus 55 MGD from the existing EBWF wells are needed to deliver a total EBWF capacity of 70 MGD. This assumes each well can produce 1,000 gpm and 10 percent are out of service for O&M. Assuming 60 MGD is supplied from Cheney and 70 MGD is supplied from the EBWF, the total raw water supply of 130 MGD is adequate to meet the year 2045 demand projection of 128 MGD. Twenty RRWs are included in the capital improvements plan and include manual transfer switches to support portable emergency power generators.

13.2 Water Treatment

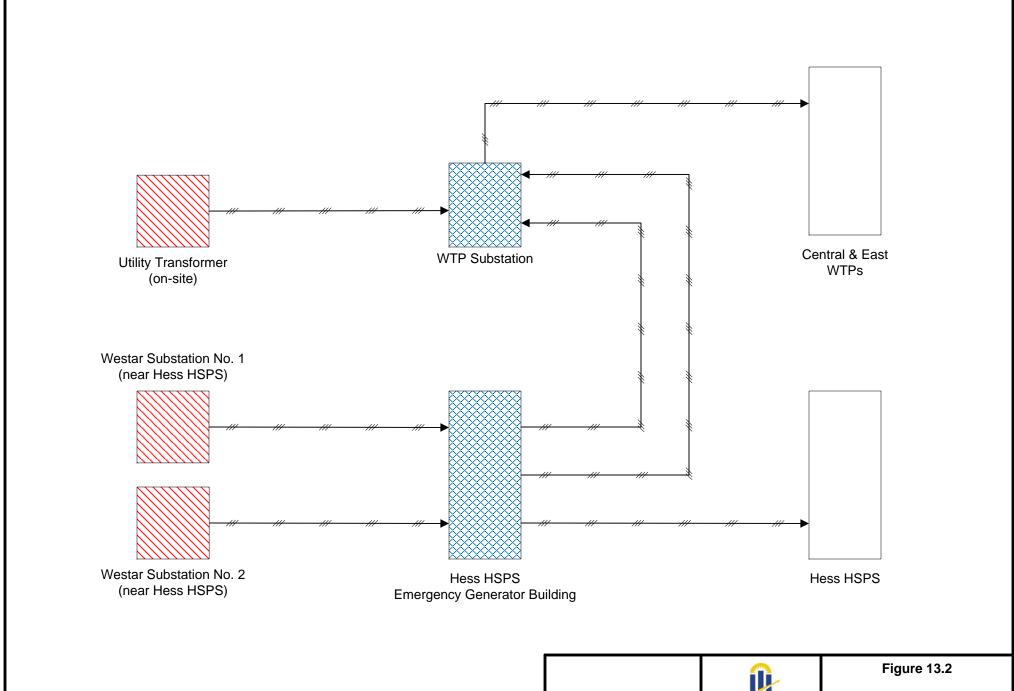
13.2.1 Emergency Power

Power is delivered to the WTP by two 5kV feeder circuits that run underground from the switchgear located in the Hess HSPS emergency generator building. Each circuit originates from separate 5kV buses which, in turn, are fed from separate and redundant utility transformers owned by Westar. At the WTP, both circuits are connected to double throw fused switches before connecting to the primary side of separate 2,500kVA transformers that provide 480V power to the WTP's main 480V switchgear. The 480V switchgear is configured with two main breakers, a tie breaker, and several feeder breakers that supply power to WTP MCCs and various loads. The Main-Tie-Main arrangement of the switchgear allow for either transformer to supply power for all WTP loads.

There are two primary sources of backup power available to the WTP if both utility services above become unavailable and are briefly described below:

- No. 1: The switchgear gear lineups that provide the circuits to the WTP are currently backed-up by the Hess HSPS emergency generators. In the event of a utility outage on both Westar feeds, the generators will automatically provide power to Hess HSPS and the WTP.
- No. 2: A third feed from Westar is available if the primary two feeds and the emergency
 generators become unavailable. In order for the third feed to be used, the WTP must be manually
 isolated from the switchgear in the Hess HSPS generator building by opening the fused switches
 mentioned above, and then manually closing the emergency feed switches, thereby restoring
 power to the WTP.

A high level representation of the power flow is depicted in Figure 13.2. The power supply arrangement and connection of the distribution equipment described above is based on review of several record drawings provided by the City and discussions with WTP staff. There does not appear to be a single document in the City's records that accurately depicts the current arrangement of the power distribution at Hess HSPS, the emergency generator facility, and the WTP combined. Therefore, a study is recommended that establishes an accurate one-line diagram showing the arrangement and capacity of the transformers, generators, and distribution buses to better understand how the various power sources operate together in terms of primary and emergency power capability.







City of Wichita, Kansas

WTP & Hess HSPS Power Distribution Summary

13.2.2 Redundant Treatment

Once constructed, the East WTP Improvements project will provide clarification/softening facilities capable of treating up to 80 MGD of 100 percent groundwater or a blend of surface water and groundwater. This will improve treatment flexibility, mitigate the risk for a temporary loss of supply from the Cheney system, and provides redundancy for the primary process treatment train up to 145 MGD. One of the two primary process treatment trains (at 65 MGD each) in the Central WTP and one in the current East WTP can be out of service and still provide up to 145 MGD from the other Central Plant primary process train (65 MGD) and from the East WTP Improvements project (80 MGD). Filtration capacity will not increase with the East WTP Improvements project; therefore, the overall rated treatment capacity of 160 MGD will not increase.

The 2015 Water Resources Plan (WRP) by the City includes an additional treatment facility located near the intersection of 21st and Zoo Boulevard; this is referred to as the Northwest Treatment Plant (NWTP). A new treatment facility at a location other than the existing WTP provides treatment redundancy and helps mitigate risks associated with the total loss of treatment/production at the existing WTP site. Sizing the NWTP at 80 MGD to accommodate necessary Central Plant improvements provides the level of system-wide treatment redundancy suggested by City staff. A capital improvements plan for the NWTP is included in this water master plan.

13.3 Water Distribution

13.3.1 Emergency Power at Pumping Facilities

The current pumping capacity with backup power serving the Northeast pressure zone is approximately 8.0 MGD from Webb Road PS and is not capable of delivering the 2015 peak hour demand (10.8 MGD) plus fire flow requirement (5.0 MGD (3,500 gpm)) which totals 15.8 MGD. This emergency condition represents loss of power at 37th Street BPS (no backup power) and at Webb Road PS; furthermore, the pumping capacity with backup power is not capable of delivering the 2015 maximum day demand plus the fire flow requirement which totals 10.7 MGD. Webb Road PS could deliver a 24-hour demand of 4.2 MGD that would include a peaking demand of 8.0 MGD with backup power. A current City project, titled Standby Power Generation (by others) and scheduled for construction in April 2017, includes backup power to support new pumps that replace BDP-2 (new at 3,000 gpm) and BDP-3 (new pump at 4,800 gpm) and support D1/M1 (3,475 gpm) for a total of 16.2 MGD and exceeds the peak hour plus fire flow demand for the Northeast pressure zone. The proposed pumping capacity with backup power also exceeds the year 2045 peak hour demand projection and fire flow requirement of 16.1 MGD. Therefore, backup power is not required at 37th Street BPS if the Northeast Tower is placed back in service and the

control scheme for Webb Road PS changes as indicated previously in Section 11.5. However, if the Northeast Tower remains out of service, there may be interstitial demand conditions that require 37th Street BPS; therefore, emergency power at 37th Street BPS is recommended if the Northeast Tower remains out of service.

The current pumping capacity with backup power serving the East pressure zone is 25.0 MGD from Webb Road PS and is not capable of delivering the 2015 peak hour demand (24.4 MGD) plus fire flow requirement (5.0 MGD (3,500 gpm)) which totals 29.4 MGD. This emergency condition represents loss of power at the Southeast BPS (no backup power) and at Webb Road PS; however, the pumping capacity with backup power can deliver the 2015 maximum day demand plus the fire flow requirement which totals 16.3 MGD. Webb Road PS could deliver a 24-hour demand of approximately 11.6 MGD that would include a peaking demand of 25.0 MGD with backup power. The standby power generation project discussed above also supports the Webb Road PS pumps serving the East pressure zone. The pumping capacity with backup power as indicated in construction drawings, is 37.0 MGD, and exceeds the peak hour plus fire flow requirement. The projected 2045 peak hour plus fire flow requirement is approximately 38.5 MGD; therefore, a recommendation to install additional backup power at the Southeast BPS could be made, but given the volatility of growth in the East pressure zone since 2003, additional backup power at the Southeast BPS should be delayed until development occurs and water demands escalate. The Southeast BPS is equipped with a manual transfer switch to dock a temporary or mobile emergency power generator.

The Hess HSPS pumping capacity with backup power is approximately 97.2 MGD from 3 pumps and can deliver the 2015 peak hour demand (81.0 MGD) plus fire flow requirement (10.8 MGD (7,000 gpm)) which totals 91.8 MGD for Hess pressure zone only (this does not include the East pressure zone). This emergency condition represents loss of power at Hess HSPS with no interruption to the treatment process treating and supplying the reservoir system. This review summarizes the effective pumping capacity for Hess pressure zone and provides the City a quantitative method to size capital improvements for additional backup power to cover other operational goals for emergency service as determined by the City. Some examples of potential operational goals are listed below:

- Providing backup power for the Hess pressure zone projected 2045 peak hour plus fire flow demand of 122 MGD for four (4) pumps at Hess HSPS with a combined pumping capacity estimated at 122.4 MGD (at 264 ft of pump head).
 - The caveat with this operational goal (example only) is the treatment capacity of the
 WTP. The emergency conditions assume the WTP can treat and supply the Hess

Reservoir system at a rate equal to what can be pumped out by Hess HSPS. The rated treatment capacity of the Main WTP is 160 MGD, but the operational capacity is less and potentially limited by hydraulic bottlenecks, backwashing capability, and/or filter loading; therefore, if the operational treatment capacity is less than Hess HSPS pumping capacity, then the recommendation to increase backup power has a diminishing return until the operational treatment capacity is increased above 122.4 MGD.

- Note, since the East pressure zone has no storage and is supplied by the Hess pressure zone, sizing backup power to support 122 MGD will be shared with East pressure zone demands.
- Providing some portion or all of the East pressure zone demand conditions. For example, assuming the 2015 peak hour in the Hess (81.0 MGD) and East (24.4 MGD) pressure zones occurs simultaneously, plus the fire flow requirement of Hess pressure zone at 10.8 MGD, requires backup power to support a total of 116.1 MGD.
- Note, fire protection for customers with high requirements up to 7,000 gpm, or a portion thereof, can be the responsibility of the customer; therefore, the City should develop a comprehensive list of customers with high fire flow requirements and respective protection responsibilities. This could affect future capital improvement recommendations for backup power. For clarity, even if the full fire flow requirement, in terms of pumping, is not required, the equivalent fire protection volume in Hess reservoir system should be maintained.
- Also of note, the primary power and backup power study discussed and recommended in Section 13.2.1 should be completed before capital improvements for additional backup power at Hess HSPS are evaluated further. Additionally, it is reasonable for the City to reduce recreational water use and implement water use restrictions for the customer population in an emergency situation that temporarily terminates primary power from Westar at Hess HSPS.

Water demands in West Maple pressure zone are delivered via pumping from West Maple BPS, which has no backup power. This BPS is sized to deliver maximum day and peak hour demands and boost pressure in the western-most part of the distribution system. Fire flow is conveyed from Hess pressure zone via check valves in the distribution system upstream of West Maple BPS. If West Maple BPS loses power, then, under current maximum day and peak hour demands, the model indicates adequate flow and pressure (greater than 25 psi) can be provided while repairs are made. Since fire flow is provided by Hess pressure zone, a fire flow condition with a loss of power at West Maple BPS is not a basis fire adding backup power; the existing West Maple BPS is not sized to deliver fire flow. The addition of backup

power should be revisited as development occurs and water demands increase above the projections indicated for this area.

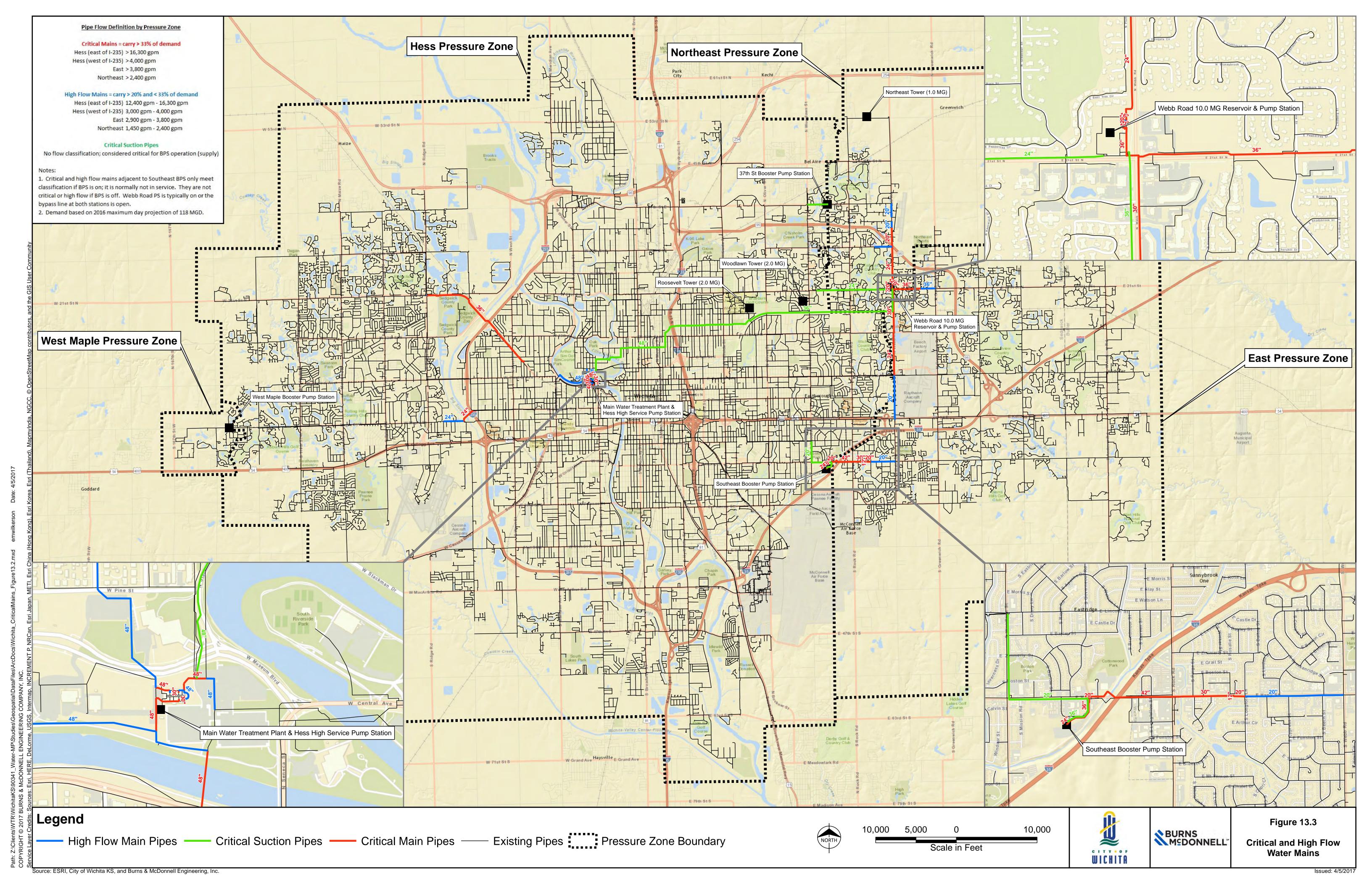
13.3.2 Water Main Criticality

There are two water main classifications, critical mains and high flow mains, used to characterize flow conditions specific to the City's distribution system hydraulics. Critical mains are considered those carrying greater than 33 percent of the maximum day demand. High flow mains are considered those carrying greater than 20 percent and less than 33 percent of the maximum day demand. Critical and high flow water mains in the City's distribution system are better characterized on a pressure zone basis because BPS supply mains in an upstream pressure zone are as important, or critical, as those bound by the flow parameters indicated above. Therefore, a sub-set of critical mains, referred to as critical suction piping, is also included in this evaluation.

Critical mains, high flow mains, and critical suction piping is illustrated in Figure 13.3 and is based on the 2016 system-wide maximum day demand of 118 MGD. As indicated in the previous paragraph, the flow parameters are based on the maximum day demand of each pressure zone. With respect to Hess pressure zone, an additional level of criticality is included to account for the distribution system west and east of I-235, or the "big ditch" which is a natural divide in the pressure zone, because there are only six water mains that establish this east-west connection. Therefore, critical and high flow mains shown in the Hess pressure zone are defined by the maximum day demand represented west of I-235 and east of I-235. Also of note, critical mains, high flow mains, and critical suction piping adjacent to the Southeast BPS only reflect these flow classifications if the BPS is active; these water mains are not considered critical or high flow if the BPS is off. This is noteworthy because the City does not typically operate the Southeast BPS and, therefore, the critical mains, high flow mains, and critical suction piping adjacent to the Webb Road BPS (serving the East pressure zone) are typically more significant with respect to system operation.

13.3.3 Emergency Storage

Emergency storage represents the amount of storage remaining after the equalization and fire storage requirements are accounted for. The equalization and fire storage volumes represent the minimum storage requirement that should always be available. Emergency storage must also be considered effective storage. For example, the bottom portion of the Hess reservoir system is not considered effective storage because Hess HSPS cannot operate below a level of 4 ft in the reservoirs; therefore, the equivalent volume represented by 4 ft cannot be allocated for emergency storage. The amount of emergency storage, when available, is typically determined by the municipality. In instances where there is a surplus of emergency storage available, the full amount does not have to be stored if water quality becomes an issue.



An abundance of emergency storage also provides an opportunity to lower or optimize active storage volumes, as is the case with Webb reservoir.

Webb reservoir provides equalization, fire protection, and a surplus of emergency storage for the Northeast pressure zone. Depending on the amount of emergency storage desired by the City, there is a surplus of approximately 5.2 MG that can be allocated as such. The storage allocations for Webb reservoir are illustrated in Figure 13.4 and include potential operating levels of three (3) scenarios which vary the amount of emergency storage. A brief description of the scenarios evaluated for varying levels of emergency storage are listed below and include the minimum storage requirement (fire and equalization storage):

- Scenario No. 1: designating half the 2015 average day demand for emergency storage requires 3.1 MG of active storage which represents an operating range from 7.0 ft to 13.2 ft.
 - Based on average day demand of 3.6 MGD, the emergency storage volume is equivalent to 12 hours.
 - Based on a maximum day demand of 5.7 MGD, the emergency storage volume is equivalent to approximately 8 hours.
- Scenario No. 2: designating half the emergency storage surplus represents an operating range from 7.0 ft to 14.8 ft.
 - Based on the 2015 average day demand of 3.6 MGD, the emergency storage volume is equivalent to 17 hours.
 - Based on the 2015 maximum day demand of 5.7 MGD, the emergency storage volume is equivalent to approximately 11 hours.
- Scenario No. 3: designating 18 hours of emergency storage for the 2015 maximum day demand represents an operating range from 7.0 ft to 18.2 ft.
 - Under the 2015 average day demand of 3.6 MGD, the emergency storage volume is equivalent to 29 hours.
- The head range of Webb reservoir is 20.0 ft and the storage volume below 7.0 ft in the reservoir is considered ineffective due to pumping limitations as indicated by City staff. If the ineffective water level is closer to 4 ft or 5 ft, then the potential operating levels (active head range) will shift down.

A current City project, titled Standby Power Generation (by others), includes a new vacuum priming system for the pumps serving the Northeast pressure zone. If the new system provides full use of Webb reservoir head range and the entire volume is termed effective, then new potential operating levels can be

Storage Allocations Total Storage = 10.00 MG Effective Storage = 6.50 MG Minimum Storage Requirement = 1.31 MG Equalization Storage = 0.68 MG Fire Protection Storage = 0.63 MG Reduction = 5.19 MG Emergency Storage = 5.19 MG Active Storage F Potential = Ineffective Storage = 3.5 MG

Equalization Storage

Equalization Factor = 0.12 2015 Maximum Day Demand = 5.7 MGD Storage = $0.12 \times 5.7 \text{ MGD} \times 1 \text{ day}$

Fire Protection

Fire Flow Requirement = 3,500 gpm for 3 hours Storage = $(3,500 \text{ gpm x } (60 \text{ min/hr})) \times 3 \text{ hours}$

Emergency Storage Duration @ 5.19 MG

Year 2015

Average Day (3.6 MGD) Maximum Day (5.7 MGD) 1.4 days 0.9 days

35 hours

Ineffective Storage

22 hours

Volume below 7.0 ft (pump suction limitation) Volume per ft = 0.5 MG/ft Storage = $0.5 MG/ft \times 7.0 ft$

Effective Storage = 6.5 MG 7.0 ft

Operating Level

20.0 ft

0.0 ft :

Ineffective Storage = 3.5 MG

Webb Road 10.0 MG Reservoir

NOT TO SCALE

Potential Operating Levels: Active Storage Reduction Potential = Emergency Storage

*Minimum Storage Requirement ((MSR), fire + equalization) = 1.31 MG *Volume per ft = 0.5 MG/ft

Scenario No. 1

City designates half the average day demand for emergency storage Storage = $3.1 \text{ MG} = ((0.5 \times 1 \text{ day}) \times 3.6 \text{ MGD}) + \text{MSR}$ Equivalent Storage Range = 6.2 ft

Scenario No. 2

City designates half the available emergency storage Storage = $3.9 \text{ MG} = (5.19 \text{ MG} \times 0.5) + \text{MSR}$ Equivalent Storage Range = 7.8 ft

Scenario No. 3

City designates 18 hours of emergency storage on the maximum day demand Storage = $5.6 \text{ MG} = (18 \text{ hrs x} (1/24 \text{ hrs/day}) \times 5.7 \text{ MGD}) + \text{MSR}$ Equivalent Storage Range = 11.2 ft





Figure 13.4

City of Wichita, Kansas

Northeast Pressure Zone Emergency Storage Summary

20.0 ft **Potential Operating Levels** abla 14.8 ft 13.2 ft Scenario No. 3 Scenario No. 2 Scenario No. 1 7.0 ft 7.0 ft 7.0 ft Ineffective Storage 0.0 ft

Webb Road 10.0 MG Reservoir

Webb Road 10.0 MG Reservoir

evaluated based on the City's determination of emergency storage. Furthermore, if the Northeast Tower is placed back in service, then effective storage for the Northeast pressure zone will increase and would impact potential operating levels if fire protection and a portion of the equalization storage is satisfied by the elevated tower.

The Hess reservoir system provides equalization, fire protection, and a small surplus of emergency storage for the Hess, East, and West Maple pressure zones. Depending on the amount of emergency storage desired by the City, there is a surplus of approximately 14.6 MG that can be allocated. The storage allocations for the Hess reservoir system is illustrated in Figure 13.5 and also includes potential operating levels of three (3) scenarios with varying amounts of emergency storage. A brief description of the scenarios evaluated for varying levels of emergency storage are listed below and include the minimum storage requirement:

- Scenario No. 1: designating the minimum storage requirement only (no emergency storage) of 11.1 MG represents an operating head range from 4.0 ft to 8.9 ft.
- Scenario No. 2: designating half the available emergency storage represents an operating head range from 4.0 ft to 11.9 ft.
 - Based on the 2015 average day demand of 46.1 MGD, the emergency storage volume is equivalent to 3.8 hours.
 - Based on the 2015 maximum day demand of 72.2 MGD, the emergency storage volume is equivalent to approximately 2.5 hours.
- Scenario No. 3: designating all available emergency storage represents an operating head range from 4.0 ft to 15.0 ft.
 - Based on the 2015 average day demand of 46.1 MGD, the emergency storage volume is equivalent to 7.6 hours.
 - Based on the 2015 maximum day demand of 72.2 MGD, the emergency storage volume is equivalent to approximately 4.9 hours.
- Note, the head range of the Hess reservoir system is 15.0 ft. The storage volume below 4.0 ft is considered ineffective due to pumping limitations as indicated by City staff; this also assumes the pumps are operational above a water level of 7.0 ft.

Due to pump suction limitations and operational requirement that pumps must be started above a water level of 7.0 ft, it is recommended that the reservoir system be operated from 7.0 ft to 20.0 ft which covers the minimum storage requirement and 3.1 ft of emergency storage (equivalent to approximately 7.2 MG). If the vacuum priming system, as recommended in the CIP, is implemented and the full head range is

Equalization Storage

Equalization Factor = 0.13 2015 Maximum Day Demand = 72.2 MGD Storage = 0.13 x 72.2 MGD x 1 day

Fire Protection

Fire Flow Requirement = 7,000 gpm for 4 hours Storage = (7,000 gpm x (60 min/hr)) x 4 hours

Emergency Storage Duration @ 14.6 MG

Year 2015

Average Day (46.1 MGD) Maximum Day (72.2 MGD)

0.3 days

7.6 hours

4.9 hours

Ineffective Storage

Volume below 4.0 ft (pump suction limitation)
Volume per ft = 2.34 MG/ft
Storage = 2.34 MG/ft x 4.0 ft

Effective Storage = 25.7 MG

4.0 ft

Ineffective Storage = 9.4 MG

Operating Level

15.0 ft

0.0 ft :

NOT TO SCALE

Hess Reservoir System, 35.1 MG

Potential Operating Levels V 11.9 ft V 8.9 ft Scenario No. 2 Scenario No. 1 Ineffective Storage 0.0 ft

Hess Reservoir System, 35.1 MG

Hess Reservoir System, 35.1 MG

Potential Operating Levels: Active Storage Reduction Potential = Emergency Storage

Notes:

*Minimum Storage Requirement ((MSR), fire + equalization) = 11.1 MG *Volume per ft = 2.34 MG/ft

Scenario No. 1

City designates MSR only Storage = 11.1 MG = 9.4 MG + 1.7 MG Equivalent Storage Range = 4.9 ft

Scenario No. 2

City designates half the available emergency storage Storage = 18.4 MG = (14.6 MG x 0.5) + MSR Equivalent Storage Range = 7.9 ft

Scenario No. 3

City designates all available emergency storage Storage = 25.7 MG = 14.6 MG + MSR Equivalent Storage Range = 11.0 ft





Figure 13.5

City of Wichita, Kansas

Hess, East, & West Maple Pressure Zones Emergency Storage Summary termed effective, then new potential operating levels can be evaluated based on the City's determination of emergency storage.

* * * * *

14.0 CAPITAL IMPROVEMENTS PLAN

Opinions of probable cost for capital improvements previously discussed are provided in this section of the report. Costs opinions are organized by planning period, classification, size, and pressure zone where applicable. Capital improvement classifications, or triggers, for linear projects include hydraulic, growth (development driven), fire, and redundancy; linear projects are recommended for the raw water and water distribution systems. Hydraulic improvements have a higher priority because they are required to support the demand projections and associated distribution system hydraulics; there is no prioritization for future growth improvements which should be implemented when and where development is occurring. Fire flow improvements can be implemented as funding is available and prior to the planning period it is recommended in. Raw water linear improvements are redundancy driven to improve the reliability of the system and should ultimately be scheduled based on recommended condition assessments of the four major raw water transmission mains.

Capital improvement classifications, or triggers, for vertical projects include capacity, replacement, redundancy, and regulatory. Capacity and regulatory based improvements have the highest priority as they are required for compliance and to support the demand projections; replacement driven improvements have a lower priority because the City has continued to successfully manage the system despite their limitations (i.e. functionality, partial use, regulatory, etc.), but are still required to improve operations. Redundancy driven improvements can be implemented at the City's discretion.

14.1 Cost Estimating Procedures

These order-of-magnitude cost opinions prepared by Burns & McDonnell relating to costs, quantities, demand or pricing (including, but not limited to, property costs, construction, operations or maintenance costs, and/or energy or commodity demand and pricing), are opinions based on Burns & McDonnell's experience, qualifications, judgment, and information from vendors and published sources such as Means. Burns & McDonnell has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's means and methods, unavoidable delays, construction contractor's method of pricing, demand or usage, population demographics, market conditions, changes in technology, government regulations and laws, and other economic or political factors affecting such opinions. The City of Wichita acknowledges that actual results may vary significantly from the representations and opinions herein, and nothing herein shall be construed as a guarantee or warranty of conclusions, results, or cost opinions. Burns & McDonnell makes no guarantee or warranty (actual or implied) that actual rates, demand, pricing, costs, performance, schedules, quantities, technology, and related items will not vary from the opinions contained in the estimates, projections, results, or other

statements or opinions prepared by Burns & McDonnell. The construction cost index for Kansas City, August 2016, is 11371.00.

14.2 Unit Cost Development for Linear Distribution System Improvements

Unit cost information for linear capital improvements in the water distribution system are based on a collection of over 50 recent water main projects since 2014 for the City of Wichita. The unit cost per diameter (inch)*linear feet for pipe improvements within City limits are estimated at \$9.35/diameter*inch and includes pavement removal and replacement. A unit cost of \$4.50 per diameter (inch)*linear feet is applied to improvements beyond existing City limits and assumes no pavement removal or replacement; these are primarily classified as growth related improvements. Typical water main construction items used in the unit cost development are detailed in Table 14.1 below:

Basic Water Main Components	Pavement Replacement	Miscellaneous	Other Potential Items	
Pipe	Pavement Repair	Service Connects	Vaults	
Valves Fittings	Curb and Gutter Driveway	Service Lines Pressure Testing	Boring Casing Pipe	
Fire Hydrants Excavation	Traffic Control Demolition	Disinfection Seeding	Directional Drilling Tree Removal	
Blow Off Assemblies	Haul Off	Erosion Control Site Restoration	Rock Excavation	

Table 14.1 Water Main Construction Items

14.3 Opinions of Probable Cost

Cost opinions are provided for capital improvements in today's dollars for the raw water, water treatment, and distribution systems. There are three capital improvement plan options and include the Base Option, Option No. 1, and Option No. 2. The Base Option does not include a new WTP and Option Nos. 1 and 2 include the new NWTP, but with different treated water delivery mechanisms. The opinions of probable cost for each option is grouped as follows and summarized in Tables 14.2, 14.3, and 14.4:

- Base Option = \$387 million
- Base Option plus Option No. 1 = \$618 million
 - Option No. 1 has dedicated treated water transmission from the NWTP to Hess Reservoir system for distribution.
- Base Option plus Option No. 2 = \$599 million
 - Option No. 2 has direct service to Hess pressure zone from the NWTP and associated transmission improvements to support this in the distribution system.

Table 14.2
Cost Opinion Summary: Base Option

System	2017	2018	2020	2025	2030	2035	2045	System Subtotal
Distribution	\$123,000		\$8,600,000	-		\$1,560,000	\$30,040,000	\$40,300,000
Treatment		\$12,150,000	\$15,810,000					\$28,000,000
Raw Water ¹		\$3,200,000		\$163,290,000	\$151,790,000			\$318,300,000
Planning Period Subtotal	Planning Period Subtotal \$123,000 \$15,350,000 \$24,410,000 \$163,290,000 \$151,790,000 \$1,560,000 \$30,040,000							
Total (all systems & all planning periods)								

Notes:

1. Trigger year for raw linear improvements portion of the capital cost summary is contingent upon a condition assessment; years 2025 and 2030 are placeholders.

Table 14.3
Cost Opinion Summary: Base Option with Option No. 1

System	2017	2018	2020	2025	2030	2035	2045	System Subtotal
Distribution	\$123,000		\$8,600,000			\$1,560,000	\$30,040,000	\$40,300,000
Treatment ¹		\$12,150,000	\$15,810,000			\$231,200,000		\$259,200,000
Raw Water ²		\$3,200,000		\$163,290,000	\$151,790,000			\$318,300,000
Planning Period Subtotal	\$123,000	\$15,350,000	\$24,410,000	\$163,290,000	\$151,790,000	\$232,760,000	\$30,040,000	
Total (all systems & all planning periods)								

Notes:

- 1. If RO is not required for the NWTP, then \$17.3 million can be deducted from the cost above.
- 2. Trigger year for raw linear improvements portion of the capital cost summary is contingent upon a condition assessment; years 2025 and 2030 are placeholders.

Table 14.4
Cost Opinion Summary: Base Option with Option No. 2

	, , ,									
System	2017	2018	2020	2025	2030	2035	2045	System Subtotal		
Distribution	\$123,000		\$8,600,000			\$27,230,000	\$30,040,000	\$66,000,000		
Treatment ¹		\$12,150,000	\$15,810,000			\$186,370,000		\$214,300,000		
Raw Water ²		\$3,200,000		\$163,290,000	\$151,790,000			\$318,300,000		
Planning Period Subtotal	\$123,000	\$15,350,000	\$24,410,000	\$163,290,000	\$151,790,000	\$213,600,000	\$30,040,000			
	Total (all systems & all planning periods) \$598,600,000									

Notes:

- 1. If RO is not required for the NWTP, then \$17.3 million can be deducted from the cost above.
- 2. Trigger year for raw linear improvements portion of the capital cost summary is contingent upon a condition assessment; years 2025 and 2030 are placeholders.

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14.3.1 Base Option

The Base Option includes capital improvements for raw water, treatment, and distribution system improvements. A comprehensive listing for each improvement is listed in Table 14.5 and 14.6 for raw water, Table 14.7 for water treatment, and Tables 14.8 and 14.9 for distribution system improvements. Capital cost summaries for each system are listed below by classification/trigger:

- Raw Water System Improvements:
 - 2018/2019 Vertical
 - Hydraulic = \$3.2 million
 - o 2022 Vertical
 - Redundancy/Capacity = \$72.2 million
 - Linear trigger year to be determined based on condition assessment; placeholder years
 of 2025 and 2030 are used for EBWF and Cheney transmission respectively.
 - Redundancy = \$242.9 million
- Water Treatment Improvements:
 - o 2018 Vertical
 - Capacity = \$11.4 million
 - Replacement = \$0.3 million
 - Water Quality = \$0.4 million
 - 2020 Vertical
 - On-site Sodium Hypochlorite Generation = \$15.8 million (the existing system has always been KDHE approved, but if constructed today the existing system would be out of compliance with current codes. Therefore, the trigger for this improvement could be future regulatory and/or safety if the grandfathered-compliance status changes in the future.
- Distribution System Improvements:
 - o 2017 Linear
 - Hydraulic = \$123,000
 - 2020 Linear
 - Hydraulic = \$6.8 million
 - Future = \$400,000
 - Note, this represents CIP 2020-Hess-G-20 and was previously planned for future growth in 2045 but was accelerated to support road paving projects beginning in 2025 as indicated by City staff.
 - Fire = \$1.5 million

Table 14.5
Raw Water Vertical Improvements - Opinions of Probable Construction Cost: Base Option

		Planning Start			Capital Cost Components				
CIP Designation ¹	Trigger	Year	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴		
2018 Capital Improvements									
2018-Pressure Control Building-H-1	Hydraulic	2017	LS	\$2,000,000	\$800,000	\$400,000	\$3,200,000		
		2025 Capital II	mprovements						
2020-Bank Storage Wells-RC-1	Redundancy/Capacity	2017	LS	\$7,720,000	\$3,090,000	\$1,550,000	\$12,400,000		
2022-Recharge Recovery Wells-RC-2	Redundancy/Capacity	2019	LS	\$35,260,000	\$14,110,000	\$7,060,000	\$56,430,000		
2022-Recharge Basins-RC-3	Redundancy/Capacity	2019	LS	\$2,090,000	\$840,000	\$420,000	\$3,350,000		
	Subtotal 2025 Capital Cost Opinion \$75,380,000								

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: C = Capacity; R = Redundancy; or RC for both.
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

Table 14.6
Raw Water Linear Improvements - Opinions of Probable Construction Cost: Base Option

Year (TBD) Capital Improvements									
		Planning Start			Capital Cost	Components			
CIP Designation ¹	Trigger Year ⁵		ُ ا Unit ا	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴		
TBD-EBWF 66" Transmission-R-1	Redundancy	TBD	LS	\$56,940,000	\$22,780,000	\$11,390,000	\$91,110,000		
					Subtotal Cap	oital Cost Opinion	\$91,110,000		
		Year (TBD) Capita	I Improvements						
TBD-60" & 66"Cheney Transmission-R-2	TBD-60" & 66"Cheney Transmission-R-2 Redundancy TBD LS \$94,860,000 \$37,950,000 \$18,980,000 \$								
Subtotal Capital Cost Opinion \$									

Notes:

- CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
 Trigger: C = Capacity; R = Redundancy; or RC for both.
- Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- Capital cost opinion includes construction, contingency, and design components.
- 5. Planning start year and completion year to be determined based on condition assessment and remaining useful life; placeholder in 2025 for EBWF transmission and in 2030 for Cheney transmission.

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Table 14.7 Water Treament Vertical Improvements - Opinions of Probable Construction Cost: Base Option

	20	018 Capital Improve	ements								
		Diamaina Stort			Capital Cost	Components					
CIP Designation ¹	Trigger	Planning Start Year	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴				
2018-Washwater Process Improvements-C-2	Capacity	2017	LS	\$2,250,000	\$680,000	\$340,000	\$3,270,000				
2018-Filter Improvements-C-4	Capacity	2017	LS	\$5,630,000	\$1,690,000	\$850,000	\$8,170,000				
2018-VPS Hess HSPS-RR-1	Replacement	2017	LS	\$220,000	\$70,000	\$30,000	\$320,000				
2018-Hess Reservoir Recirculation-WQ-1	Water Qaulity	2017	LS	\$239,000	\$100,000	\$50,000	\$389,000				
					Subtotal 2018 Cap	oital Cost Opinion	\$12,150,000				
	20	020 Capital Improve	ements								
2020-On-Site Sodium Hypochlorite Generation-RG-1		2019	LS	\$10,900,000	\$70,000	\$1,640,000	\$15,810,000				
			Subtotal 2020 Capital Cost Opinion \$1!								

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: C = Capacity, R = Redundancy; RR = Replacement; WQ = water quality.

 2. Contingency at 30 percent of the construction cost.
- 3. Design at 15 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

 5. Base option does not include a new WTP.

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Table 14.8
Distribution System Linear Improvements - Opinions of Probable Construction Cost: Base Option

2017 Capital Improvements Water Main Detail Capital Cost Components											
CIP Designation ¹	Trigger	Model ID	Unit	Diameter	Quantity	Unit Cost ⁴	Planning Start	Construction ⁵	Contingency ⁶	Design ⁷	Capital Cost
2017-Hess-H-1	Hydraulic	PIPE739	LF	(in) 24	344	(\$/dia-inch*LF) \$9.35	Year 2017	\$77,100	\$30,800	\$15,400	Opinion ⁸ \$123,000
					2020 Cani	tal Improvements			Subtotal 2017 Ca	pital Cost Opinio	n \$123,000
2020-Hess-H-1	Hydraulic	PIPE677	LF	8	70	\$9.35	2019	\$5,200	\$2,100	\$1,000	\$8,300
2020-Hess-H-2 2020-Hess-H-3	Hydraulic Hydraulic	PIPE705 PIPE719	LF LF	8	64 165	\$9.35 \$9.35	2019 2019	\$4,800 \$12,300	\$1,900 \$4,900	\$1,000 \$2,500	\$7,700 \$19,700
2020-Hess-H-4	Hydraulic	PIPE667	LF	12	58	\$9.35	2019	\$6,500	\$2,600	\$1,300	\$10,400
2020-Hess-H-5 2020-Hess-H-6	Hydraulic Hydraulic	PIPE713 PIPE715	LF LF	12 12	149 80	\$9.35 \$9.35	2019 2019	\$16,700 \$9,000	\$6,700 \$3,600	\$3,300 \$1,800	\$26,700 \$14,400
2020-Hess-H-7	Hydraulic	PIPE671	LF	16	100	\$9.35	2019	\$14,900	\$6,000	\$3,000	\$23,900
2020-Hess-H-8 2020-Hess-H-9	Hydraulic Hydraulic	PIPE717 PIPE679	LF LF	16 24	174 19	\$9.35 \$9.35	2019 2019	\$26,100 \$4,200	\$10,400 \$1,700	\$5,200 \$1,000	\$41,700 \$6,900
2020-Hess-H-10	Hydraulic	PIPE683	LF	24	97	\$9.35	2019	\$21,700	\$8,700	\$4,300	\$34,700
2020-Hess-H-12	Hydraulic	PIPE691	LF	30	2,883	\$9.35	2017	\$808,700	\$323,500	\$161,700	\$1,293,900
2020-Hess-H-13 2020-Hess-H-14	Hydraulic Hydraulic	PIPE669 PIPE787	LF LF	36 8	53 115	\$9.35 \$9.35	2019 2019	\$17,700 \$8,600	\$7,100 \$3,400	\$3,500 \$1,700	\$28,300 \$13,700
2020-Hess-H-15	Hydraulic	PIPE663	LF	30	5,173	\$9.35	2017	\$1,451,000	\$580,400	\$290,200	\$2,321,600
2020-Hess-H-16 2020-Hess-H-18	Hydraulic Hydraulic	PIPE851 PIPE637	LF LF	48 12	996 4,456	\$9.35 \$4.50	2017 2017	\$447,000 \$240,600	\$178,800 \$96,200	\$89,400 \$48,100	\$715,200 \$384,900
2020-Hess-H-19	Hydraulic	PIPE641	LF	12	2,848	\$4.50	2017	\$153,800	\$61,500	\$30,800	\$246,100
2020-Hess-G-20 2020-East-H-1	Growth Hydraulic	PIPE591 PIPE681	LF LF	24 16	2,307 25	\$4.50 \$9.35	2020 2019	\$249,200 \$3,800	\$99,700 \$1,500	\$49,800 \$1,000	\$398,700 \$6,300
2020-East-H-2	Hydraulic	PIPE659	LF	30	3,460	\$9.35	2017	\$970,600	\$388,200	\$194,100	\$1,552,900
2020-Hess-F-1 2020-Hess-F-5	Fire Fire	PIPE755 PIPE765	LF LF	<u>8</u>	731 1,026	\$9.35 \$9.35	2019 2017	\$54,600 \$76,800	\$21,800 \$30,700	\$10,900 \$15,400	\$87,300 \$122,900
2020-Hess-F-8	Fire	PIPE771	LF	8	592	\$9.35	2019	\$44,300	\$17,700	\$8,900	\$70,900
2020-Hess-F-11 2020-Hess-F-12	Fire Fire	PIPE577 PIPE579	LF LF	12 12	5,241 1,613	\$4.50 \$4.50	2017 2017	\$283,000 \$87,100	\$113,200 \$34,800	\$56,600 \$17,400	\$452,800 \$139,300
2020-Hess-F-13	Fire	PIPE581	LF	12	1,661	\$4.50	2017	\$89,700	\$35,900	\$17,900	\$143,500
2020-Hess-F-14 2020-Hess-F-15	Fire Fire	PIPE583 PIPE775	LF LF	12 12	3,612 536	\$4.50 \$9.35	2017 2019	\$195,000 \$60,200	\$78,000 \$24,100	\$39,000 \$12,000	\$312,000 \$96,300
2020-Hess-F-15 2020-Hess-F-18	Fire	PIPE775 PIPE857	LF LF	8	186	\$9.35	2019	\$60,200	\$24,100	\$12,000	\$96,300
					2025.000	tal Improvements			Subtotal 2020 Ca	pital Cost Opinio	n \$8,600,000
2035-Hess-H-1	Hydraulic	PIPE701	LF	8	2035 Capi	\$9.35	2034	\$1,100	\$500	\$1,000	\$2,600
2035-Hess-H-2	Hydraulic	PIPE703	LF	8	82	\$9.35	2034	\$6,100	\$2,400	\$1,200	\$9,700
2035-Hess-H-3 2035-Hess-H-4	Hydraulic Hydraulic	PIPE721 PIPE665	LF LF	8 12	163 217	\$9.35 \$9.35	2034 2034	\$12,200 \$24,300	\$4,900 \$9,700	\$2,400 \$4,900	\$19,500 \$38,900
2035-Hess-H-6	Hydraulic	PIPE711	LF	12	62	\$9.35	2034	\$7,000	\$2,800	\$1,400	\$11,200
2035-Hess-H-7 2035-Hess-H-8	Hydraulic Hydraulic	PIPE673 PIPE697	LF LF	16 16	48 3,781	\$9.35 \$9.35	2034 2032	\$7,100 \$565,600	\$2,800 \$226,200	\$1,400 \$113,100	\$11,300 \$904,900
2035-Hess-H-9	Hydraulic	PIPE725	LF	16	14	\$9.35	2034	\$2,100	\$800	\$1,000	\$3,900
2035-Hess-H-11 2035-East-H-1	Hydraulic Hydraulic	PIPE699 PIPE709	LF LF	20 12	163 18	\$9.35 \$9.35	2034 2034	\$30,400 \$2,000	\$12,200 \$800	\$6,100 \$1,000	\$48,700 \$3,800
2000 2001 11	rryaraano	111 27 03					2034	\$2,000	Subtotal 2035 Ca		
2045-Hess-G-1	Growth	PIPE495	LF	12	2045 Capi 5,436	\$4.50	2042	\$293,500	\$117,400	\$58,700	\$469,600
2045-Hess-G-2	Growth	PIPE497	LF	12	5,229	\$4.50	2042	\$282,400	\$113,000	\$56,500	\$451,900
2045-Hess-G-3 2045-Hess-G-5	Growth Growth	PIPE499 PIPE503	LF LF	12 12	333 4,444	\$4.50 \$4.50	2044 2042	\$18,000 \$240,000	\$7,200 \$96,000	\$3,600 \$48,000	\$28,800 \$384,000
2045-Hess-G-6	Growth	PIPE505	LF	12	5,375	\$4.50	2042	\$290,300	\$116,100	\$58,100	\$464,500
2045-Hess-G-7	Growth	PIPE507 PIPE509	LF LF	12 12	4,100	\$4.50	2042	\$221,400	\$88,600	\$44,300 \$30,800	\$354,300 \$246,500
2045-Hess-G-8 2045-Hess-G-9	Growth Growth	PIPE509 PIPE511	LF	12	2,853 5,334	\$4.50 \$4.50	2042 2042	\$154,100 \$288,000	\$61,600 \$115,200	\$57,600	\$460,800
2045-Hess-G-10	Growth	PIPE513	LF	12	2,653	\$4.50	2042	\$143,300	\$57,300	\$28,700	\$229,300
2045-Hess-G-11 2045-Hess-G-12	Growth Growth	PIPE515 PIPE517	LF LF	12 12	5,205 5,577	\$4.50 \$4.50	2042 2042	\$281,000 \$301,200	\$112,400 \$120,500	\$56,200 \$60,200	\$449,600 \$481,900
2045-Hess-G-13	Growth	PIPE519	LF	8	4,690	\$4.50	2042	\$168,800	\$67,500	\$33,800	\$270,100
2045-Hess-G-14 2045-Hess-G-15	Growth Growth	PIPE525 PIPE527	LF LF	12 12	5,248 5,242	\$4.50 \$4.50	2042 2042	\$283,400 \$283,100	\$113,400 \$113,200	\$56,700 \$56,600	\$453,500 \$452,900
2045-Hess-G-16	Growth	PIPE529	LF	12	5,292	\$4.50	2042	\$285,800	\$114,300	\$57,200	\$457,300
2045-Hess-G-17 2045-Hess-G-18	Growth Growth	PIPE531 PIPE533	LF LF	12 12	5,187 1,359	\$4.50 \$4.50	2042 2042	\$280,100 \$73,400	\$112,000 \$29,400	\$56,000 \$14,700	\$448,100 \$117,500
2045-Hess-G-19	Growth	PIPE537	LF	12	1,594	\$4.50	2042	\$86,100	\$34,400	\$17,200	\$137,700
2045-Hess-G-21 2045-Hess-G-22	Growth Growth	PIPE541 PIPE547	LF LF	16 12	1,437 2,008	\$4.50 \$4.50	2042 2042	\$103,400 \$108,400	\$41,400 \$43,400	\$20,700 \$21,700	\$165,500 \$173,500
2045-Hess-G-23	Growth	PIPE549	LF	12	5,597	\$4.50	2042	\$302,200	\$120,900	\$60,400	\$483,500
2045-Hess-G-24 2045-Hess-G-25	Growth Growth	PIPE551 PIPE553	LF LF	12 12	5,305 5,535	\$4.50 \$4.50	2042 2042	\$286,500 \$298,900	\$114,600 \$119,600	\$57,300 \$59,800	\$458,400 \$478,300
2045-Hess-G-26	Growth	PIPE555*	LF	12	5,261	\$4.50	2042	\$284,100	\$113,600	\$56,800	\$454,500
2045-Hess-G-27 2045-Hess-G-28	Growth Growth	PIPE557 PIPE559*	LF LF	12 12	5,205 5,035	\$4.50 \$4.50	2042 2042	\$281,100 \$271,900	\$112,400 \$108,800	\$56,200 \$54,400	\$449,700 \$435,100
2045-Hess-G-29	Growth	PIPE561	LF	12	5,296	\$4.50	2042	\$286,000	\$114,400	\$57,200	\$457,600
2045-Hess-G-30 2045-Hess-G-31	Growth Growth	PIPE563 PIPE565	LF LF	12 12	1,690 5,259	\$4.50 \$4.50	2042 2042	\$91,300 \$284,000	\$36,500 \$113,600	\$18,300 \$56,800	\$146,100 \$454,400
2045-Hess-G-31 2045-Hess-G-34	Growth	PIPE571	LF	16	3,572	\$4.50	2042	\$257,200	\$102,900	\$51,400	\$411,500
2045-Hess-G-37	Growth	PIPE585*	LF 15	12	5,292	\$4.50	2042	\$285,800	\$114,300	\$57,200	\$457,300
2045-Hess-G-38 2045-Hess-G-39	Growth Growth	PIPE587* PIPE589	LF LF	12 12	5,237 3,469	\$4.50 \$4.50	2042 2042	\$282,800 \$187,300	\$113,100 \$74,900	\$56,600 \$37,500	\$452,500 \$299,700
2045-Hess-G-41	Growth	PIPE593	LF	12	1,489	\$4.50	2042	\$80,400	\$32,200	\$16,100	\$128,700
2045-Hess-G-42 2045-Hess-G-43	Growth Growth	PIPE595* PIPE597	LF LF	12 12	5,118 5,251	\$4.50 \$4.50	2042 2042	\$276,400 \$283,600	\$110,600 \$113,400	\$55,300 \$56,700	\$442,300 \$453,700
2045-Hess-G-44	Growth	PIPE599	LF	12	5,209	\$4.50	2042	\$281,300	\$112,500	\$56,300	\$450,100
2045-Hess-G-45 2045-Hess-G-46	Growth Growth	PIPE601 PIPE605	LF LF	12 12	5,065 1,231	\$4.50 \$4.50	2042 2042	\$273,500 \$66,500	\$109,400 \$26,600	\$54,700 \$13,300	\$437,600 \$106,400
2045-Hess-G-47 ¹¹	Growth	PIPE607	LF	12	481	\$71.16	2042	\$410,700	\$164,300	\$82,100	\$657,100
2045-Hess-G-48	Growth	PIPE609	LF I E	12	5,177 5,363	\$4.50 \$4.50	2042	\$279,600	\$111,800 \$115,800	\$55,900 \$57,900	\$447,300
2045-Hess-G-49 2045-Hess-G-50	Growth Growth	PIPE611* PIPE613	LF LF	12 12	5,363 5,223	\$4.50 \$4.50	2042 2042	\$289,600 \$282,000	\$115,800 \$112,800	\$57,900 \$56,400	\$463,300 \$451,200
2045-Hess-G-51	Growth	PIPE615	LF	12	5,250	\$4.50	2042	\$283,500	\$113,400	\$56,700	\$453,600
2045-Hess-G-52 2045-Hess-G-53	Growth Growth	PIPE617 PIPE619	LF LF	12 12	5,273 5,231	\$4.50 \$4.50	2042 2042	\$284,700 \$282,500	\$113,900 \$113,000	\$56,900 \$56,500	\$455,500 \$452,000
2045-Hess-G-54	Growth	PIPE621	LF	12	5,419	\$4.50	2042	\$292,600	\$117,000	\$58,500	\$468,100
2045-Hess-G-55 2045-Hess-G-56	Growth Growth	PIPE623* PIPE625*	LF LF	12 12	5,323 5,272	\$4.50 \$4.50	2042 2042	\$287,400 \$284,700	\$115,000 \$113,900	\$57,500 \$56,900	\$459,900 \$455,500
2045-Hess-G-57	Growth	PIPE625	LF LF	12	2,537	\$4.50 \$4.50	2042	\$137,000	\$113,900	\$36,900	\$455,500
2045-Hess-G-58	Growth	PIPE629	LF 1E	12	5,281	\$4.50 \$4.50	2042	\$285,200	\$114,100	\$57,000 \$43,700	\$456,300
2045-Hess-G-59 2045-Hess-G-60	Growth Growth	PIPE631 PIPE633	LF LF	12 12	4,047 2,631	\$4.50 \$4.50	2042 2042	\$218,600 \$142,100	\$87,400 \$56,800	\$43,700 \$28,400	\$349,700 \$227,300
2045-Hess-G-61	Growth	PIPE799	LF	12	2,720	\$4.50	2042	\$146,900	\$58,800	\$29,400	\$235,100
2045-Hess-G-63 2045-Hess-G-65	Growth Growth	PIPE639 PIPE777	LF LF	12 12	3,181 2,619	\$4.50 \$9.35	2042 2017	\$171,800 \$293,800	\$68,700 \$117,500	\$34,400 \$58,800	\$274,900 \$470,100
2045-Hess-G-66	Growth	PIPE469	LF	12	3,498	\$4.50	2042	\$188,900	\$75,600	\$37,800	\$302,300
2045-East-G-1		PIPE443	LF	12	2,196	\$4.50	2042	\$118,600	\$47,400	\$23,700	\$189,700

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Table 14.8 Distribution System Linear Improvements - Opinions of Probable Construction Cost: Base Option

					2017 Capi	tal Improvements					
					Water Main De	tail		Ca	pital Cost Compone	ents	
CIP Designation ¹	Trigger	Model ID	Unit	Diameter (in)	Quantity	Unit Cost⁴ (\$/dia-inch*LF)	Planning Start Year	Construction ⁵	Contingency ⁶	Design ⁷	Capital Cost Opinion ⁸
2045-East-G-3	Growth	PIPE447	LF	12	4,715	\$4.50	2042	\$254,600	\$101,800	\$50,900	\$407,300
2045-East-G-4	Growth	PIPE449*	LF	12	5,148	\$4.50	2042	\$278,000	\$111,200	\$55,600	\$444,800
2045-East-G-5	Growth	PIPE451*	LF	12	5,289	\$4.50	2042	\$285,600	\$114,200	\$57,100	\$456,900
2045-East-G-6	Growth	PIPE453	LF	12	5,178	\$4.50	2042	\$279,600	\$111,800	\$55,900	\$447,300
2045-East-G-7	Growth	PIPE455*	LF	12	5,241	\$4.50	2042	\$283,000	\$113,200	\$56,600	\$452,800
2045-East-G-8	Growth	PIPE457*	LF	12	5,333	\$4.50	2042	\$288,000	\$115,200	\$57,600	\$460,800
2045-East-G-9	Growth	PIPE459*	LF	12	5,270	\$4.50	2042	\$284,600	\$113,800	\$56,900	\$455,300
2045-East-G-10	Growth	PIPE461*	LF	12	5,309	\$4.50	2042	\$286,700	\$114,700	\$57,300	\$458,700
2045-East-G-13	Growth	PIPE467*	LF	12	5,218	\$4.50	2042	\$281,700	\$112,700	\$56,300	\$450,700
2045-East-G-14	Growth	PIPE473	LF	12	1,045	\$4.50	2044	\$56,400	\$22,600	\$11,300	\$90,300
2045-East-G-15	Growth	PIPE475*	LF	12	5,278	\$4.50	2042	\$285,000	\$114,000	\$57,000	\$456,000
2045-East-G-16	Growth	PIPE477*	LF	12	5,476	\$4.50	2042	\$295,700	\$118,300	\$59,100	\$473,100
2045-East-G-17	Growth	PIPE479	LF	12	2,847	\$4.50	2042	\$153,700	\$61,500	\$30,700	\$245,900
2045-East-G-18	Growth	PIPE481*	LF	12	5,279	\$4.50	2042	\$285,100	\$114,000	\$57,000	\$456,100
2045-East-G-19	Growth	PIPE483	LF	12	2,648	\$4.50	2042	\$143,000	\$57,200	\$28,600	\$228,800
2045-East-G-20	Growth	PIPE485	LF	12	5,373	\$4.50	2042	\$290,200	\$116,100	\$58,000	\$464,300
2045-East-G-21	Growth	PIPE487	LF	12	5,411	\$4.50	2042	\$292,200	\$116,900	\$58,400	\$467,500
2045-East-G-22	Growth	PIPE489	LF	12	2,855	\$4.50	2042	\$154,200	\$61,700	\$30,800	\$246,700
2045-Northeast-G-1	Growth	PIPE493	LF	12	8,997	\$4.50	2042	\$485,900	\$194,400	\$97,200	\$777,500
	Subtotal 2045 Growth Capital Cost Opinion \$30,040,000										

- CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 - Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Fire flow improvements prioritized as funding is available
- 3. Growth improvements prioritized as future development occurs.
- 4. Future growth areas outside City limits (peripheral growth) does not include pavement removal and replacement; future growth areas inside City limits (infill growth) and a

hydraulic and fire flow improvements includes pavement removal and replacement

- 5. Construction cost for horizontal improvements (excludes pump improvements) is based on unit cost
- 6. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 7. Design at 20 percent of the construction cost; minimum design cost is \$1,000. 8. Capital cost opinion includes construction, contingency, and design components.
- 9. Base conditions do not include a new WTP.
- 10. Model IDs with an asterisk (*) represent pipes that extend into neighboring water suppliers or rural water districts where the City has designated some portion therein as a future growth area 11. Unit cost at \$4.50/dia-inch*LF plus \$800/LF for for horizontal boring.

Table 14.9
Distribution System Vertical Improvements - Opinions of Probable Construction Cost: Base Option

	2035 Capital Improvements									
	Planning Start Capital Cost Compone					Components				
CIP Designation ¹	Trigger	Type	Unit	Year	Construction	Cti2	D:3	Capital Cost		
				rear	Construction	Contingency ²	Design³	Opinion ⁴		
2035-West Maple BPS-H-1	Hydraulic	Pump	LS	2034	\$15,000	\$6,000	\$3,000	\$24,000		
2035-SE BPS-H-1	Hydraulic	Pump	LS	2032	\$310,000	\$120,000	\$60,000	\$490,000		
Subtotal 2035 Capital Cost Opinion										

- CIP Designation definition = CIP Year-Pump Station-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven)
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Base conditions do not include a new WTP.

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- o 2035 Linear
 - Hydraulic = \$1.1 million
- o 2035 Vertical
 - Hydraulic = \$0.5 million
 - Pump additions at West Maple BPS and Southeast BPS
- o 2045 Linear
 - Growth = \$30.0 million

14.3.2 Option No. 1

Option No. 1 includes the new NWTP and dedicated finished water transmission from the site at 21st and Zoo Boulevard to the Hess Reservoir system and is additive to the Base Option improvements. An itemized listing for each improvement is listed in Table 14.10. The capital cost summary is listed below by classification/trigger:

- Water Treatment Improvements
 - 2035 Vertical
 - Redundancy = \$186.4 million (includes 13.3 MGD of RO)
 - If RO is not required, then \$17.3 million can be deducted from the cost above.
 - o 2035 Linear
 - Redundancy = \$44.8 million

14.3.3 Option No. 2

Option No. 2 includes the new NWTP with direct service to the distribution system and is additive to the Base Option. An itemized listing for each improvement is listed in Tables14.11 and 14.12. The capital cost summary is listed below by classification/trigger:

- Water Treatment Improvements:
 - o 2035 Vertical
 - Redundancy = \$186.4 million (includes 13.3 MGD of RO)
 - If RO is not required, then \$17.3 million can be deducted from the cost above.
- Distribution System Improvements:
 - o 2035 Linear
 - Redundancy = \$25.7 million

14.4 Capital Planning Schedule

Capital planning schedules for all linear and vertical improvements are included in Appendix I. Linear improvements include a thumbnail picture for locational orientation in the system and facility location for

Table 14.10
Water Treatment Vertical and Linear Improvements - Opinions of Probable Construction Cost: Option 1

2035 Capital Improvements								
		Planning Start	Unit	Capital Cost Components				
CIP Designation ¹	Trigger	Year		Construction	C	Daniau ³	Capital Cost	
				Construction	Contingency	Design ³	Opinion ⁴	
2035-Northwest WTP-R-1	Redundancy	2032	LS	\$133,120,000	\$39,940,000	\$13,310,000	\$186,370,000	
2035-Finished Water Transmission-R-2	Redundancy	2032	LS	\$28,020,000	\$11,210,000	\$5,600,000	\$44,830,000	
Subtotal 2035 Capital Cost Opinion \$231,2								

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: R = Redundancy.
- 2. Contingency at 30 percent of the construction cost for 2035-Northwest WTP-R-1; contingency at 40 percent for 2035-Finished Water Transmission-R2.
- 3. Design at 10 percent of the construction cost for 2035-Northwest WTP-R-1; design at 20 percent for 2035-Finished Water Transmission-R2.
- 4. Capital cost opinion includes construction, contingency, and design components.

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Table 14.11
Distribution System Linear Improvements - Opinions of Probable Construction Cost: Option 2

	2035 Capital Improvements								
			Planning Start			Capital Cost	Components		
CIP Designation ¹	Model ID	Trigger	Year	Unit	Construction	Contingency ²	Design ³	Capital Cost	
			Teal		Construction	Contingency	Design	Opinion ⁴	
2035-Hess-Option 2-H-1	PIPE795, PIPE797	Hydraulic	2032	LS	\$16,040,000	\$6,420,000	\$3,210,000	\$25,670,000	
Subtotal 2035 Capital Cost Opinion								\$25,670,000	

- CIP Designation definition = CIP Year-Pressure Zone-Option-Trigger-Sequential Numbering
 Trigger: H = Hydraulic; Option = Option 2
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

Table 14.12
Water Treatment Vertical Improvements - Opinions of Probable Construction Cost: Option 2

2035 Capital Improvements									
Diamaina Stant				Capital Cost Components					
CIP Designation ¹	Trigger	Planning Start Year	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion4		
2035-Northwest WTP-R-1	Redundancy	2032	LS	\$133,120,000	\$39,940,000	\$13,310,000	\$186,370,000		
Subtotal 2035 Capital Cost Opinion \$186,370,									

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: C = Capacity; R = Redundancy.
- 2. Contingency at 30 percent of the construction cost.
- 3. Design at 10 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

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vertical improvements is described in the CIP designation/name. Vertical improvements include a general itemized listing of the components included in the cost opinion.

14.5 Economic Evaluations

Economic evaluations include a present worth analysis to compare the present value of Option No. 1 and Option No. 2 and determining the operation and maintenance (O&M) cost to produce water for each option. These options include a new NWTP with the following variations:

- Option No. 1 includes dedicated finished water transmission from a new NWTP to the finished water reservoir system at the existing WTP for high service pumping to the distribution system.
- Option No. 2 includes finished water with direct service to the distribution system from a new NWTP.

These options represent the lowest common denominators for the capital improvements plan. The Base Option for raw water and water distribution system capital improvements are recommended regardless of the capital improvements associated with Option No.'s 1 and 2; therefore, they are not included in the economic evaluations. The present worth analysis for both options includes the following components:

- Capital Costs:
 - o Beginning in year 2035 and inflated to year 2035 dollars.
 - Option No. 1 includes NWTP and transmission (linear).
 - Option No. 2 includes NWTP and distribution system improvements (linear) required to support direct service.
- Operations and maintenance (O&M) Costs:
 - o Beginning in year 2035 and inflated to year 2035 dollars.
 - O Pumping energy: Option No. 1 based on the horsepower required to deliver 50 percent of the average day demand to Hess reservoir system. Option No. 2 results in an energy savings because the horsepower required to deliver the total average day demand from two locations is lower than what is required to deliver the total from one location (i.e. existing WTP as is the case with Option No. 1).
 - o RO Energy cost for 13.3 MGD of RO treatment.
 - O Chemical: based on the highest 4-year chemical costs for the existing WTP which occurred in 2015 at \$0.10/1,000 gallons.
 - Membrane and cartridge filter replacement: annual replacement cost.
 - Wages: based on existing WTP personnel wages in 2015; assumes a similar workforce is required. Wages for a superintendent, lab director, maintenance supervisor, and a clerk

are not included; it is assumed these positions will not need to be duplicated for the NWTP.

- Other variables and assumptions:
 - o Inflation: capital costs at 3.5 percent, energy cost at 4.0 percent, equipment replacement and chemical costs at 3.5 percent, and plant personnel wages at 3.0 percent.
 - o Interest at 6.0 percent.
 - Energy at \$0.06/KW*hr based on an average of the monthly energy bills for Hess HSPS and Central WTP in 2015.
 - O&M costs for pumping energy, treatment energy, and chemical assumes the NWTP produces 50 percent of the average day demand.
 - Average day demand based on the water demand projections discussed in Section
 3.0 throughout the planning period through year 2045.
 - o Piping and Pumping:
 - Steel pipe with inner diameter equal to the recommended size, AWWA C200 standards with cement mortar lining.
 - C-value of 110 and minor loss coefficient of 3.
 - Wire-to-water efficiency of 67.5 percent.

The present worth analysis for Option No. 1 is included in Table 14.13 and results in a present value of \$197,286,000. The present worth analysis for Option No. 2 is included in Table 14.14 and results in a present value of \$183,899,000. By the 2045 planning period the O&M cost of water for Option No. 1 and Option No. 2 is \$1.74/1,000 gallons and \$1.70/1,000 gallons respectively and is also listed in Tables 14.13 and 14.14.

14.6 Non-economic Evaluations

Non-economic considerations for redundancy driven improvements associated with the raw water system and water treatment facilities are listed below:

- Raw Water Transmission: To Be Decided (TBD) (year)-EBWF 66" Transmission-R-1, TBD(year)-Cheney 60" & 66" Transmission-R-2
 - o Advantages:
 - The existing transmission main could be removed from service for maintenance or repair without impacting surface water availability.
 - Water supply will be unavailable if a main break occurs until repairs can be made.

Table 14.13

New Northwest WTP Present Worth Analysis - Option No. 1

	Capita	l Cost ¹			Operatio	n and Maintenand	ce Costs ²					Average Day	O&M Cost of
Year	Treatment	Transmission	NWTP Transfer			Membrane &	Other			Total Present	Present Value	Demand ⁴	Water
rear	2035-NWTP-R-1	2035-FWT-R-2	Pumping Energy ⁵	RO Energy ⁶	Chemical ⁷	Cartridge Filter Replacement	Replacement ⁸	Wages ⁹	Total O&M	Value ³	Cummulation	(MGD)	(\$/1,000 gal)
2016													
2017													
2018													
2019													
2020													
2021													
2022													
2023													
2024													
2025													
2026													
2027													
2028													
2029													
2030													
2031													
2032													
2033													
2034													
2035	\$358,297,000	\$86,174,000	\$208,000	\$4,307,000	\$2,467,000	\$0	\$0	\$4,876,000	\$11,858,000	\$150,823,000	\$150,823,000	35.15	\$0.92
2036			\$217,000	\$4,479,000	\$2,556,000	\$1,990,000	\$2,278,000	\$5,022,000	\$16,542,000	\$5,158,000	\$155,981,000	35.19	\$1.29
2037			\$226,000	\$4,658,000	\$2,648,000	\$2,059,000	\$2,358,000	\$5,173,000	\$17,122,000	\$5,037,000	\$161,018,000	35.23	\$1.33
2038			\$235,000	\$4,845,000	\$2,744,000	\$2,132,000	\$2,441,000	\$5,328,000	\$17,725,000	\$4,919,000	\$165,937,000	35.27	\$1.38
2039			\$245,000	\$5,038,000	\$2,843,000	\$2,206,000	\$2,526,000	\$5,488,000	\$18,346,000	\$4,803,000	\$170,740,000	35.31	\$1.42
2040			\$255,000	\$5,240,000	\$2,946,000	\$2,283,000	\$2,614,000	\$5,652,000	\$18,990,000	\$4,690,000	\$175,430,000	35.35	\$1.47
2041			\$266,000	\$5,449,000	\$3,053,000	\$2,363,000	\$2,706,000	\$5,822,000	\$19,659,000	\$4,581,000	\$180,011,000	35.39	\$1.52
2042			\$277,000	\$5,667,000	\$3,163,000	\$2,446,000	\$2,801,000	\$5,997,000	\$20,351,000	\$4,473,000	\$184,484,000	35.43	\$1.57
2043			\$288,000	\$5,894,000	\$3,278,000	\$2,532,000	\$2,899,000	\$6,177,000	\$21,068,000	\$4,369,000	\$188,853,000	35.47	\$1.63
2044			\$300,000	\$6,130,000	\$3,396,000	\$2,620,000	\$3,000,000	\$6,362,000	\$21,808,000	\$4,266,000	\$193,119,000	35.51	\$1.68
2045			\$312,000	\$6,375,000	\$3,519,000	\$2,712,000	\$3,105,000	\$6,553,000	\$22,576,000	\$4,167,000	\$197,286,000	35.55	\$1.74
Totals	\$358,297,000	\$86,174,000		-	-					\$197,286,000		-	

- 1. Capital cost inflated at 3.5 percent.
- 2. Energy inflated at 4.0 percent; chemical and equipment replacement inflated at 3.5 percent; plant personnel wages inflated at 3.0 percent.
- 3. Present value with fixed interest at 6.0 percent
- 4. Average day demand is half of the demand projection; assumes 50 percent of the average day demand is treated by the NWTP and 50% is treated by the existing WTP.
- 5. Energy costs for water transfer from NWTP to Hess reservoir system for distribution system pumping; this does not represent Hess HSPS energy costs.
- 6. RO energy for 13.3 MGD of RO treatment.
- 7. Chemical is based on the highest 4-year chemical costs for the existing WTP which occurred in 2015 at \$0.10/1,000 gallons.
- 8. Other replacement is estimated at 2 percent of the non-membrane and non-filtration capital cost without markups.
- 9. Wages are based on inflated 2015 expenditures for existing water treatment and pumping personnel less the wages for a superintendent, lab director, maintenance supervisor, and clerk

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Table 14.14
New Northwest WTP Present Worth Analysis - Option No. 2

	Ca	pital Cost ¹			Operati	on and Maintenar	ice Costs ²					Average Day	O&M Cost of
Year	Treatment 2035-NWTP-R-1	Distribustons	Pumping Energy Savings ⁵	RO Energy ⁶	Chemical ⁷	Membrane & Cartridge Filter Replacement	Other Replacement ⁸	Wages ⁹	Total O&M	Total Present Value ³	Present Value Cummulation	Demand ⁴ (MGD)	Water (\$/1,000 gal)
2016													
2017							-						
2018							-						
2019													
2020													
2021													
2022													
2023													
2024													
2025													
2026													
2027													
2028													
2029													
2030													
2031													
2032													
2033													
2034													
2035	\$358,297,000	\$49,351,000	-\$157,000	\$4,307,000	\$2,467,000	\$0	\$0	\$4,876,000	\$11,493,000	\$138,532,000	\$138,532,000	35.15	\$0.90
2036			-\$163,000	\$4,479,000	\$2,556,000	\$1,990,000	\$2,278,000	\$5,022,000	\$16,162,000	\$5,039,000	\$143,571,000	35.19	\$1.26
2037			-\$170,000	\$4,658,000	\$2,648,000	\$2,059,000	\$2,358,000	\$5,173,000	\$16,726,000	\$4,920,000	\$148,491,000	35.23	\$1.30
2038			-\$177,000	\$4,845,000	\$2,744,000	\$2,132,000	\$2,441,000	\$5,328,000	\$17,313,000	\$4,804,000	\$153,295,000	35.27	\$1.34
2039			-\$184,000	\$5,038,000	\$2,843,000	\$2,206,000	\$2,526,000	\$5,488,000	\$17,917,000	\$4,691,000	\$157,986,000	35.31	\$1.39
2040			-\$192,000	\$5,240,000	\$2,946,000	\$2,283,000	\$2,614,000	\$5,652,000	\$18,543,000	\$4,580,000	\$162,566,000	35.35	\$1.44
2041			-\$200,000	\$5,449,000	\$3,053,000	\$2,363,000	\$2,706,000	\$5,822,000	\$19,193,000	\$4,472,000	\$167,038,000	35.39	\$1.49
2042			-\$208,000	\$5,667,000	\$3,163,000	\$2,446,000	\$2,801,000	\$5,997,000	\$19,866,000	\$4,367,000	\$171,405,000	35.43	\$1.54
2043			-\$216,000	\$5,894,000	\$3,278,000	\$2,532,000	\$2,899,000	\$6,177,000	\$20,564,000	\$4,264,000	\$175,669,000	35.47	\$1.59
2044			-\$225,000	\$6,130,000	\$3,396,000	\$2,620,000	\$3,000,000	\$6,362,000	\$21,283,000	\$4,164,000	\$179,833,000	35.51	\$1.64
2045			-\$235,000	\$6,375,000	\$3,519,000	\$2,712,000	\$3,105,000	\$6,553,000	\$22,029,000	\$4,066,000	\$183,899,000	35.55	\$1.70
Totals	\$358,297,000	\$49,351,000								\$183,899,000			

- 1. Capital cost inflated at 3.5 percent.
- 2. Energy inflated at 4.0 percent; chemical and equipment replacement inflated at 3.5 percent; plant personnel wages inflated at 3.0 percent.
- 3. Present value with fixed interest at 6.0 percent
- 4. Average day demand is half of the demand projection; assumes 50 percent of the average day demand is treated by the NWTP and 50% is treated by the existing WTP.
- 5. Pumping the total average day demand from two locations (new NWTP and existing WTP) requires less pressure than pumping the total demand from one location (i.e. Option No. 1).
- 6. RO energy for 13.3 MGD of RO treatment.
- 7. Chemical is based on the highest 4-year chemical costs for the existing WTP which occurred in 2015 at \$0.10/1,000 gallons.
- 8. Other replacement is estimated at 2 percent of the non-membrane and non-filtration capital cost without markups.
- 9. Wages are based on inflated 2015 expenditures for existing water treatment and pumping personnel less the wages for a superintendent, lab director, maintenance supervisor, and clerk.

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- Redundant transmission can mitigate difficulties in procuring pipe sections, fittings, and valves of this size.
- Issues with mobilization delays due to the limited number of qualified contractors to perform emergency work is diminished with redundant transmission.
- Year-EBWF 66" Transmission-R-1: provides redundant transmission capacity from the EBWF to 21st & Zoo Boulevard. Timing of installation should be based on a condition assessments to be completed as a future project.
- Year-60" & 66" Cheney Transmission-R-2: when the East WTP Improvements project is complete and raw water is blended downstream of the sleeve valves at the WTP then, under static conditions, the maximum pressure at the WTP on the existing Cheney line can reach 108 psi which exceeds the design operating pressure of 80 psi. This improvement will remove operational concerns associated with pressure.

Disadvantages:

- Land acquisition and easements.
- Constructability in high traffic and densely populated residential and commercial areas.
- Increasing asset inventory requires additional maintenance, i.e. air release valves, in-line valves, cathodic protection if required, etc.

Raw Water Facilities

- o Bank Storage Wells (2020-Bank Storage Wells-RC-1)
 - Advantages:
 - Capture above base flow river conditions (below 65 cfs) that the ASR intake facility cannot.
 - Provides a diversion mechanism for side stream storage.
 - Provide peaking assistance with respect to raw water supply needs.
 - Disadvantages:
 - Production cannot be relied on when flows are at or below baseflow in the river.
 - Above base flow events are less likely to occur during drought periods.
- o RRWs (2022-Recharge Recovery Wells-RC-2)
 - Advantages:
 - Increase production capacity from EBWF.

- Increase recharge capacity into EBWF.
- Provide more opportunity to evenly distribute recharge throughout the well field to prevent mounding.
- More production options available, on an individual well basis, when existing wells are temporarily out of service for maintenance.
- Needed to meet the long-term water supply needs if maximum day demands approach 160 MGD (estimated in 2060 in the City's Water Resources Plan), assuming the capacity of Cheney PS and transmission main is restored to 80 MGD.
- Disadvantages:
 - Increasing asset inventory requires additional maintenance.
- o Recharge Basins (2022-Recharge Basins-RC-3)
 - Advantages:
 - Provide operational flexibility during recharge events and for aquifer recharge.
 - Disadvantages:
 - Increasing asset inventory requires additional maintenance.
- Water Treatment
 - On-site Sodium Hypochlorite Generation (2020-On-Site Sodium Hypochlorite Generation-Trigger-1)
 - Advantages:
 - Safety of the disinfection application is increased.
 - Disinfectant storage for liquid is safer than gas for the amount required.
 - Removes risk associated with chlorine storage (gas) leak.
 - Reduces hazardous chemical storage requirements.
 - Disadvantages:
 - None.
 - o New 80-MGD NWTP (Option No.'s 1 and 2)
 - Advantages:
 - Provides total treatment redundancy of 160 MGD.
 - Continue delivering up to 80 MGD with loss of the existing treatment process upstream of the chlorine contact basin.
 - Disadvantages:

- Increasing the system treatment capacity with a new NWTP will increase maintenance needs and operational complexity.
- RO concentrate disposal permitting associated with deep injection wells if selected as the disposal mechanism.
- o Option No. 1 (dedicated transmission to Hess Reservoir system)
 - Advantages:
 - Single delivery point for distribution system is maintained.
 - No operational changes with respect to high service pumping.
 - No changes with respect to distribution system monitoring, analysis, or regulatory requirements.
 - Disadvantages:
 - Transmission constructability in residential areas with dense population.
 - Does not provide high service pumping redundancy for the distribution system.
 - Transmission break would effectively take the NWTP offline until corrected.
 - Can increase water age and reduce chlorine residual before entering the distribution system; may require additional disinfectant application in Hess reservoir system.
- o Option No. 2 (direct pumping/service to distribution system from NWTP)
 - Advantages:
 - Improve operational flexibility for water delivery to the distribution system.
 - High service pumping from two locations is anticipated to lower the average operating pressure in Hess pressure zone.
 - Increase the total and effective storage capacity for the distribution system and/or remove some portion of the storage in Hess Reservoir system in a manner that improves water age and turnover in reservoirs that have historically low chlorine residuals.
 - Continue providing water to customers during emergency situations if Hess HSPS is out of service.
 - Potential to retire a portion of the existing pumps at Hess HSPS.
 - Improve managing the control pressure of 92 psi at Central and Main.

Disadvantages:

- Complexity of distribution system operation increases; but, will also improve operational flexibility.
- Additional regulatory sampling requirements in the distribution system.

14.7 Financial Analysis

14.7.1 Approach and Initial Findings

The primary goal of this financial assessment is to evaluate rate stability and debt service coverage implications with the proposed capital improvement plans to achieve the following objectives:

- Evaluate current usage levels and prepare revenue forecast.
- Project capital flow of funds.
- Project operating revenue requirements.
- Review and finalize operating cash flow.

Our analytic approach includes the development of cash flow models that test the ability of revenues under existing rates to meet future operating and capital requirements of the system. For the master plan, this includes a forecast period beginning fiscal year (FY) 2016 through FY 2045. The sufficiency of revenues under existing rates was evaluated for three scenarios, including the base case, and two options (Option 1 and Option 2) that include the design and construction of a new water treatment plant. Table 14.15 summarizes findings regarding revenue sufficiency.

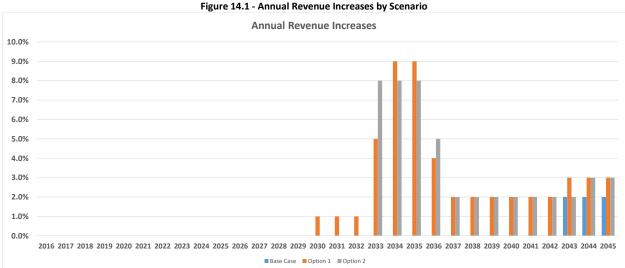
Table 14.15 - Revenue Sufficiency Findings

	2017 - 2045 Cumulative %			
Scenario	Increase	Total CIP	Total Debt Funded	Total Cash Funded
Base Case	6.12%	\$517,963,500	\$205,500,000	\$312,463,500
Option 1	64.49%	\$898,848,800	\$639,000,000	\$259,848,800
Option 2	61.19%	\$867,342,900	\$613,000,000	\$254,342,900

The cumulative increase shown in the second column of Table 14.15 signals that revenue under existing rates is not sufficient to adequately fund future revenue requirements. In all three scenarios, revenue increases are indicated to be necessary. For the Base Case, a total revenue increase through 2045 amounts to about 6 percent. Option 1 and Option 2 are indicated to need higher levels of total revenue increases through 2045, amounting to about 64 percent for Option 1 and 61 percent for Option 2.

The most significant funding requirement is the implementation of the capital improvements identified in the master plan scenarios. These improvements, inflated from current dollars used in the master plan scenarios, total about \$518 million for the Base Case, and nearly \$899 million for Option 1 and \$867 million for Option 2. A substantial portion of the capital improvement program for each scenario is anticipated to be funded from debt issuance. Additional operating cost has been added for the new Northwest Water Treatment Plant beginning in 2035 in Option 1 and Option 2.

Table 14.15 indicates cumulative revenue increases to range from about 6 percent to about 65 percent, depending on scenario. The annual revenue adjustments are illustrated in Figure 14.1 below. Depending on the scenario, annual increase range from a low of 0 percent to a high of 9 percent.



No increase is indicated to be necessary under any scenario until FY 2030. The reason this is possible is that demand is projected to return to a level higher than experienced in the last four years due to prevailing climate conditions. For instance, FY 2016 water rate revenues amounted to approximately \$75 million, while FY 2017 water rate revenues are forecasted to be nearly \$90 million, an increase that is primarily driven by an assumed return to more normal demand. This increase provides additional cash that can be used to fund capital projects and inflationary increases in operation and maintenance expenses.

14.7.2 **Key Assumptions**

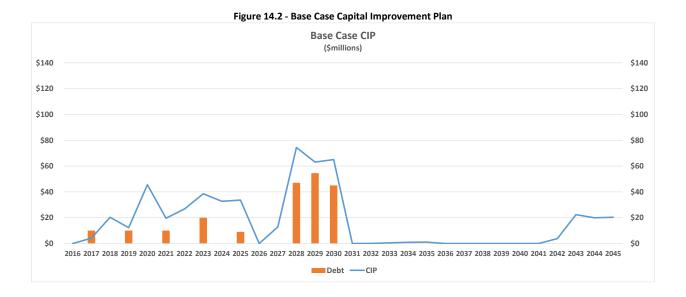
Cash flow projections involve reliance upon assumptions regarding future conditions. Key assumptions used in this analysis include the following:

- Demand forecast/water production forecast. Forecasted demand is consistent with demand anticipated in the master planning projections. Average day demand is expected to increase from 50.8 MGD in FY 2016 to 66.9 MGD in FY 2020, with further increases to 70.3 MGD in FY 2035 and then to 71.1 MGD in FY 2045. Demand is estimated to increase linearly between all milestone projections.
- Operation and maintenance expenses. Budgeted operation and maintenance expense (O&M) is reflected for fiscal years 2017 and 2018. General inflation of 3.4 percent per year is assumed for O&M in subsequent years. Additionally, Options 1 and 2 have incremental O&M expenses beginning in FY 2035 related to the operation of the new water treatment plant.
- Capital Improvement Plan. Capital improvements forecasted through the study period reflect the master planning projects cited within this report, which are based in current year dollars. Capital improvements are inflated at 3.0 percent annually.
- **Debt issuance terms.** Debt issuance is anticipated to be necessary for all scenarios. All debt is assumed to be in the form of water revenue bonds with a 20-year term. Average interest rates are assumed to be 5.0 percent for debt issued in 2017, increasing to 5.5 percent by 2019 and remaining at that level throughout the remainder of the study period. Debt issuance costs are assumed to be 2 percent of gross bond proceeds.
- Fund Balances and Targets. The beginning Operating Balance was provided by the City as of the end of FY 2015. The minimum target for the operating fund is at least 60 days of O&M, which is achieved in all scenarios. Monies in excess of the minimum target are made available to fund capital projects. Capital fund balances are set to be at least 25 percent of the following year's capital improvement plan.
- **Debt Service Coverage Targets**. The utility measures debt service coverage on revenue bonds, and all debt. For cash flow planning purposes, the minimum annual debt service coverage ratio is 1.20x on all debt including general obligation bonds. As a practical matter, most scenarios achieve minimum forecasted debt service coverage of 1.50x on all debt. During the course of the study period, the existing debt service fully amortizes. By the end of the study period, only the proposed revenue bonds are anticipated to be outstanding.

14.7.3 Capital Improvement Funding

In the Base Case, Figure 14.1 indicates no revenue increases are anticipated until FY 2043 which is primarily a function of increased demand and revenue throughout the forecast period. Figure 14.2 below summarizes the Base Case capital improvement plan. Total improvements per year are represented by the

blue line. The inflated Capital Improvement Plan (CIP) peaks at approximately \$74 million in 2028, falling to \$0 by 2031.



Debt issuance is represented by the orange bars in Figure 14.2. The amount of cash used to finance the CIP is represented by the distance between the bars and the CIP line. Figure 14.2 indicates that through FY 2028, much of the CIP can be financed with cash coming from existing balances and future cash flows. More substantial debt issuance is anticipated during FY 2028 through 2030. Remaining CIP projects forecasted in FY 2042 through FY 2045 are projected to be completely cash funded.

Figure 14.3 summarizes the CIP and funding plan for Option 1. Similar to the Base Case, initial CIP is anticipated to be funded with both cash and debt. The Option 1 CIP peaks in FY 2033 to FY 2035 due to the construction of the new water treatment plant. The inflated CIP totals approximately \$369 million during this three year period, and much of that requirement is expected to be debt financed. In FY 2036, the Option 1 CIP drops to \$0 until FY 2042 when additional growth related projects are anticipated.

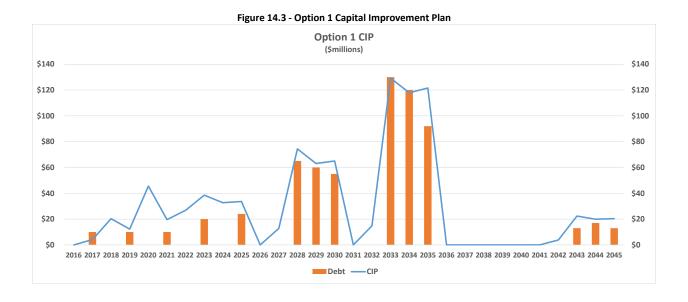
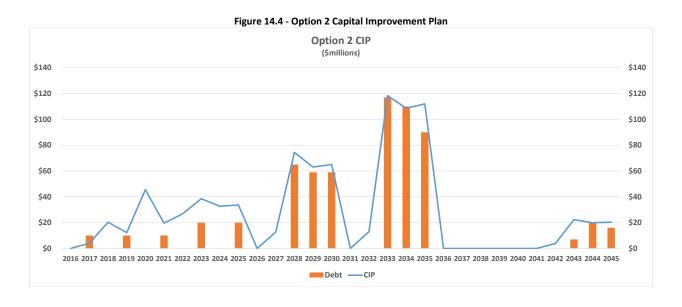


Figure 14.4 summarizes the CIP and funding plan for Option 2. Similar to the Base Case, initial CIP is anticipated to be funded with both cash and debt. As with Option 1, the capital plan peaks in FY 2033 to FY 2035 due to the construction of the new water treatment plant. In Option 2, the inflated CIP is slightly lower than Option 1 at approximately \$339 million during this three year period. As in the previous scenario, the Option 2 CIP drops to \$0 in FY 2036 until FY 2042 when additional growth related projects are identified.

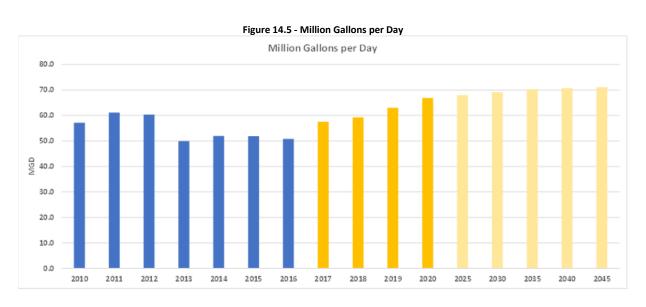


14.7.4 Important Caveats

It is important to recognize some caveats regarding the financial analysis performed for the master plan scenarios.

- 1. Capital improvement plans are limited to only the projects identified in the master plan. To the extent other projects or initiatives are underway or planned, especially within the next 5-10 years, such projects are not included unless they are reflected in the master plans. This approach provides a basis for comparing master plan scenarios, but the indicated revenue increases do not provide funding for projects or initiatives outside the proposed master plan capital improvements.
- It is assumed that any existing water capital balance available at the beginning of FY 2016 is committed to other water utility projects and is not available for use in this master plan assessment. In doing so, all master plan projects are assumed to be funded from either future cash flow or issuance of debt.
- 3. Water utility rate revenues have ranged from approximately \$63 million to \$75 million per year from 2013 to 2016, a period of time with unusually higher than typical precipitation. During this time, average day water production has been about 51 mgd. The FY 2017 water utility budget anticipates water rate revenues of approximately \$90 million, with the expectation that water demand is more consistent with average climate conditions and historic usage levels. Should water demand fail to achieve forecasted levels, the need for additional revenue increases beyond those indicated for each scenario are anticipated.

Figure 14.5 shows the recent history and projections of water average demand through FY 2045. Annual forecasts are shown in Figure 14.5 for FY 2017 through FY 2020. Beyond FY 2020, Figure 14.5 shows



five year intervals. Annual cash flow modeling assumes linear increases in demand from year to year to achieve the indicated milestones.

The increase in demand shown from FY 2016 to FY 2017 is the anticipated result of a return to generally normal climate conditions and demand levels. FY 2018 through FY 2020 includes continued normal climate conditions and additional growth as developed in the master plan.

The increased demand correlates to increased revenue. Figure 14.6 shows the historical and projected revenue over the same time intervals as Figure 14.5. Rate revenue is anticipated to increase from about \$75 million in FY 2016 to about \$90 million in FY 2017, consistent with utility budgets. This increase provides substantial cash flow which is used to fund capital projects.

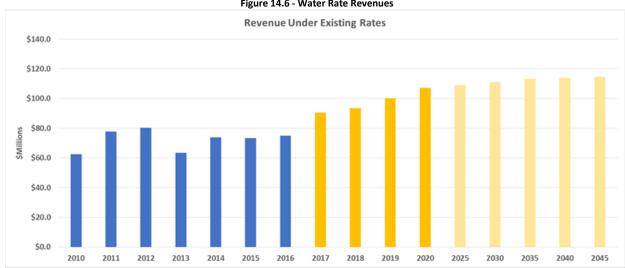


Figure 14.6 - Water Rate Revenues

In our analysis of financial impacts associated with capital plans, the assumption that demand returns to a more "normal" level in 2017 and is sustained through the study period is a material assumption. Absent the cash flow created by the assumed increase in demand, revenue increases required to fund the proposed capital plans would be substantially higher.

Detailed Cash Flows 14.7.5

Detailed cash flows for each scenario may be found in Appendix J. These cashflows provide the basis for the tabular and graphic summaries presented in Section 14.7 of this Report.

* * * *



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Water Master Plan - Appendices Burns & McDonnell Project No. 90341

July 2017

2016 Water & Sewer Master Plans

prepared for

City of Wichita, Kansas

Water Master Plan - Appendices
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July 2017

prepared by

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APPENDIX B - FIRE HYDRANT TESTING

APPENDIX C – DIURNAL CURVE CALCULATIONS

APPENDIX D - CITY ISO REPORT

APPENDIX E - STORAGE CALCULATIONS

APPENDIX F – RAW WATER MODEL DATA

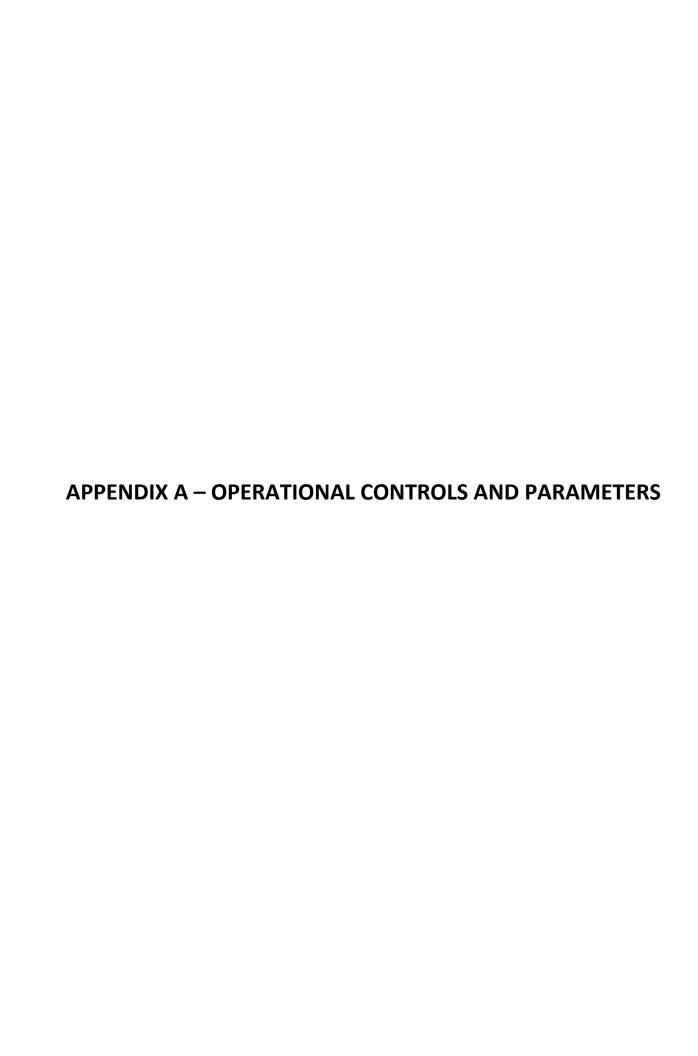
APPENDIX G - FEDERAL AND STATE REGULATIONS

2016 Water Master Plan Executive Summary

APPENDIX I – TEMPERATURE DATA

APPENDIX I – CAPITAL PLANNING SCHEDULES

APPENDIX J – CASH FLOW



Meeting Notes



Meeting Subject: Distribution System Operation

Meeting Date: April 7, 2016 Start Time: 9:00 AM End Time: 12:00 PM

Location: Central Water Treatment Plant

Project Name: Water Master Plan

Project No.: 90341

AttendeesOrganizationMike JacobsCity of WichitaTerryl PagerCity of WichitaRandall CharlierCity of WichitaAdam McGloryCity of Wichita*Ryan ScottBurns & McDonnellMichaela RempkowskiBurns & McDonnell

Notes Prepared By: Michaela Rempkowski

Date Notes Issued: April 22, 2016

Meeting Notes:

Central Pressure Zone

- 1. Hess High Service Pump Station (HSPS), Common Conditions:
 - a. The daily volume treated is equivalent to the daily demand.
 - b. The maximum day demand is typically observed between May and September.
 - c. The peak hour demand is typically observed Sunday night or Monday Morning.
 - d. The minimum hour is commonly observed around 2:00 AM.
 - e. Treated water enters the three million gallon chlorine contact basin from the Central and East treatment plants. The water is then distributed into the pipe network that includes 5 reservoirs and Hess HSPS.
 - f. Clearwell level (upstream of the chlorine contact basin) for the Central and East WTPs are typically between 10 and 13 ft annually; between 12 and 13 ft in the summer.
 - g. Low chlorine residual is commonly measured in the three reservoirs south and east of Hess HSPS.
 - h. All reservoirs float together; one level transmitter provides level for all five reservoirs. The reservoir providing level indication is uncertain.
- 2. Pump Operation
 - a. Pump No. 5 and/or No. 7 are smaller pumps and are typically the first pumps in operation.

^{*} Indicates meeting organizer

Meeting Notes (cont'd)



April 22, 2016

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- b. The north pumps include No.'s 1, 2, 5, and 6; the south pumps include No.'s 3, 4, 7, and 8. VFD capability is only one pump per odd numbered pumps and one pump per even numbered pumps (with the other pumps operating at full speed (if on). VFD status for a particular pump is at operator's discretion.
- c. Pump #2 has its own VFD.
- d. At least one pump is running at all times; one of the smaller pumps is on with VFD capability.
- e. HSPS control is based on pressure at Central and Main (pressure control under varying rates of flow).
 - i. Pressure is typically maintained between 88 and 93 psi. At 88 psi, the low pressure alarm is set off. Generally speaking, operators target 92 psi.
 - ii. At 93 psi at Central and Main, and depending on the time of day (or diurnal pattern), elevated storage in the Central PZ will fill during low demand periods.
- f. Pump combinations for Typical System Demands
 - i. 50 to 60 MGD: either No. 5 or 7 (smaller pumps and with VFD capability) and either No.'s 2, 4, 6, or 8.
 - ii. 80 to 100 MGD: two large pumps at constant speed and a smaller pump with VFD capability.
 - iii. Rare to have four or more pumps running; four pumps were run 3 years ago for approximately 1.5 hours to meet peaking demands.
 - iv. This Week (April 4-8th):
 - 1. 58 to 62 MGD: two pumps running; Pump #5 and a larger pump.
 - 2. 20 to 28 MGD: represents minimum hour and is typically the hardest demand for pump control; small pump with VFD capability.
- 3. Webb Road Reservoir
 - a. Maximum level is 20 ft, but it is typically operated between 8 ft and 12 ft; never above 18 ft
 - b. Anecdotal information from City staff indicates a minimum level of 7 ft is required for pump suction.
 - c. Reservoir fill valves are opened daily (manual control from operator workstation) to create a false demand in the system if storage at Hess reservoirs approaches higher levels, fill the Webb reservoir, prevent elevated storage in the Central PZ from overflows.
 - i. Range of operation is typically 15 percent to 45 percent open on a daily basis.
 - d. The SCADA system monitors suction pressure of the pumps and the valve position.

Northeast Pressure Zone

1. Webb Pump Station

Meeting Notes (cont'd)



April 22, 2016

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- a. Direct suction from the Webb Road reservoir.
- b.Two pumps are dedicated to the Northeast PZ; a third pump can be manually and locally transitioned (valving) to either the Northeast PZ or East PZ.
 - i. During the summer demand season, or higher demands, the transitional pump is dedicated to the Northeast PZ.
- c. The target discharge pressure range is between 50 and 60 psi.
- d. There is a 50 psi low level alarm at 34th and Webb.
- e. Pump No. 2 is always running and the larger pump cycles on as needed to maintain pressure.
- f. Only one pump (NE BPD3) runs on a VFD.

g.

2. 37th Street BPS

- a. Booster pumping service; pressure and flow provided by Central PZ. This BPS serves in a supplemental role to the Webb Road PS for the Northeast PZ if the target pressure is not maintained.
- b. During high demand periods, all of the booster pumps and both pumps dedicated to the Northeast pressure zone at Webb Pump Station can be in operation.
- c. Pump No. 1 has a mechanical governor.

East Pressure Zone

- 1. Webb Pump Station
 - a. Target discharge pressure range for pump control is 55 psi to 65 psi.
 - i. High pressure alarms at 90 psi at the east main line discharge header.
 - b. Three pumps are dedicated to the East PZ; a 4th pump can be manually and locally transitioned (valving) to either the Northeast PZ or East PZ.
 - c. Max pumping capacity is 2 pumps (one redundant) and is supplemented by the Southeast BPS if necessary.

2. Southeast BPS

a. Booster pumping service; pressure and flow provided by Central PZ. This BPS serves in a supplemental role Webb Rd Pump Station to provide adequate pressure in the East PZ, however, its use is minimal to none due to potential distribution system valving that could be recycling flow from the East PZ back into the Central PZ.

West Pressure Zone

- 1. Some low chlorine residual issues are observed in the area in the summer when school is out.
- 2. Maple BPS Pump Operation
 - a. Fully automated.
 - b. Pumps maintain discharge pressure 80 psi and a suction pressure of 53 psi. The real-time trends indicate the actual pressure is greater than 70 psi.

Meeting Notes (cont'd)



April 22, 2016

Page 4

c. Pumps alternate each time they are needed.

Elevated Storage Tanks

- 1. Northeast Tower (Northeast PZ)
 - a. The tower has been out of service for four years due to operational and turnover issues with pump control.
 - b. Tank is located on the periphery of the PZ and has little demand in that area.
- 2. The Woodlawn and Roosevelt Towers (Central PZ)
 - a. The low level alarm on both tanks is set 22 feet.
 - b. The typical operating range is between 28 and 33 ft. The overflow level is 35 ft.
 - i. Daily turnover is an operational goal.
 - ii. Turnover ranges from 8 ft to 10 ft during high seasonal demands.
 - iii. Turnover ranges from 3 ft to 4 ft during low seasonal demands.

cc: Project Files

Conference Call Minutes



Subject: Raw Water Field Testing

Date: March 25, 2016

Project Name: Water Master Plan

BMcD Project No.: 90341

On Friday, March 25th, 2016 a conference call was held to discuss the raw water field testing component of the Water Master Plan (WMP). A general summary of key discussion points is listed below:

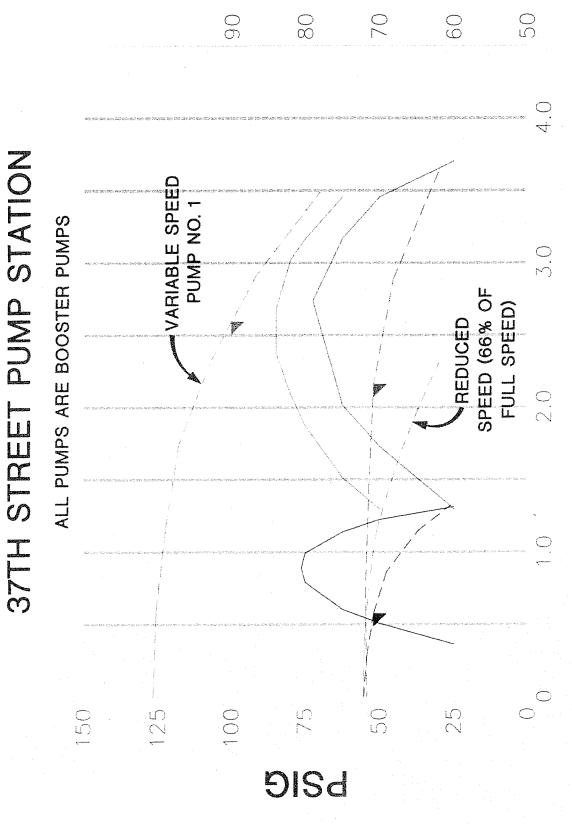
- 1. Attendees:
 - a. Burns & McDonnell (BMcD):
 - i. Ryan Scott, Project Manager
 - ii. Ty McGown, Technical Lead
 - b. City Staff:
 - i. Deb Ary, Utilities Engineer
 - ii. Mike Jacobs, Production and Pumping
 - iii. Scott Macey, Utilities Engineer
 - iv. Robert Bigley, MWTP
 - v. Terryl Pajor, MWTP
 - vi. Eric Meyer, Cheney Pump Station
 - vii. Bill Perkins, Asset Management
 - viii. Rick Moore, Equus Beds Well Field
 - ix. Larry Koontz, Équus Beds Well Field
- 2. The conference call was held to determine if the field testing efforts could be tailored to better support the production scenarios that will be evaluated in the model. Goals for the discussion included the following:
 - a. Review field testing history.
 - b. Current supply operations and field testing capability.
 - c. Production scenario definition.
- 3. Field Testing History:
 - a. Extensive field testing for model calibration verification on the Cheney pump station (PS) and transmission line was conducted in 2007.
 - i. Conclusions indicated air pockets in the transmission main accumulate and lower the capacity of the pump station and transmission main and air release valves should be checked for operation and potentially others added. Additionally, either higher head pumps, a booster pump station, or a pressure sustaining valve would be necessary to deliver 80 MGD from Cheney PS.
 - ii. Information provided by City staff during the 2007 field testing indicated that the pump station, since inception, was never tested to confirm the rated capacity.
 - iii. Cheney PS delivered between 68 and 70 MGD during the pump station capacity tests.
 - b. BMcD maintains confidence in the calibration for this portion of the raw water model and any additional testing would yield similar results; therefore, it is not recommended for the calibration confirmation efforts of this water master plan.
 - c. City Staff indicated the following:
 - i. Historical maximum capacity delivered from Cheney PS was 72 MGD for a short period of time.

Conference Call Minutes



Water Master Plan: Raw Water Field Testing Conf. Call Page 2

- ii. For a period of 1 day in July 2012, Cheney PS delivered approximately 70 MGD for about an hour; it took about 2 weeks of pumping at 60 MGD to exhaust enough air pockets to achieve 70 MGD.
- iii. 60 MGD is sustainable, but flows approaching 70 MGD are not sustainable for extended periods of time.
- iv. EBWF can deliver approximately 68 MGD (without the Bentley string of wells (wells 29-32)).
- d. Current Supply Operations and field testing capability:
 - i. Current raw water supply is approximately 40 MGD; 30 MGD from Cheney and 10 MGD from Equus Beds Well Field (EBWF).
 - ii. Cheney can deliver up to 95 percent of the total raw water supply without disrupting WTP process operations.
 - iii. EBWF can adequately deliver up to 50 percent of the total raw water supply without disrupting WTP process operations.
 - iv. Current WTP operations and system demands do not allow practical conditions for conducting stress testing on the Cheney or EBWF supplies where max capacity is desired. Conditions that allow for stress testing will not occur until the peak demands season which is July through September. The asset management project (by others) schedule for this scope item, does not allow for field testing during the peak demand season.
- 4. Production scenario definition:
 - a. The WMP scope includes hydraulic evaluation of 3 production scenarios. City staff proposed the following system conditions be evaluated in the raw water model:
 - i. Max out water supply from EBWF, no water supply from Cheney, use the 66-inch diameter well field transmission line to the MWTP, and under existing system conditions. Determine what capacity the raw water network can deliver from the EBWF.
 - ii. Max out the water supply from EBWF, no water supply from Cheney, and isolate the Cheney transmission line at Valve 187 (at/near 21st and Zoo) so all flow from EBWF is conveyed through both transmission lines to the WTP. Determine what capacity the raw water network can deliver from the EBWF.
 - iii. Max out Cheney supply and EBWF. Determine what the entire system can deliver to the WTP under existing system conditions.
 - b. Existing system conditions are defined by the following:
 - i. Current ground water pumping levels in the EBWF.
 - ii. Existing production wells in the EBWF (no future ASR phases will be evaluated).
 - iii. Valve 187 is closed at 21st and Zoo; raw water blending occurs at the WTP.
 - iv. Operational conditions are listed below:
 - 1. The Bentley string of wells (29-32) in the EBWF are not available for production/treatment at the WTP.
 - 2. No production from Bentley reserve well field or local well field.
 - 3. The recharge surge tank is isolated from the EBWF; City staff indicates better EBWF production control without the recharge surge tank.



%

MILON GALONS PER DAY (MGD)

LEGEND

PUMP 1

PUMP 2

PUMP 3

37th St BPS Specs

SECTION 1110.00

PUMPS - HIGH SERVICE

A. GENERAL

Under this item the manufacturer shall furnish and deliver, ready for installation, three (3) high service water pumps as shown on the Drawings and in agreement with the General Conditions and Supplementary General Conditions.

The pumps shall be of the horizontal, single stage, split case type, equal in construction and performance to the Series 5800 manufactured by Fairbanks Morse Pump of Kansas City, Kansas, or equal.

B. CAPACITY

Each pump shall have a capacity as shown on the Pump Calculation Summary.

C. DESIGN AND CONSTRUCTION

The impeller shall be single suction, enclosed, statically, and dynamically balanced. The impeller is to be secured against rotation on the shaft by means of a key.

Shaft Assembly: Shafting shall be made from high quality steel of sufficient diameter to carry maximum loads imposed and to prevent vibration and fatigue. The shaft shall be accurately machined along its entire length. The shaft is to be reversible to provide for opposite rotation if required. Maximum diameter shall occur where the shaft passes through the impeller hub. A keyway is to be provided at the coupling end. Renewable type shaft sleeves to protect the shaft through the stuffing box area are to be provided. The shaft sleeves shall also serve to accurately position the impeller on the shaft and within the casing. Sleeve nuts threaded on the shaft will maintain this position by ensuring that the sleeves are firmly butted against the impeller hub. A high quality mechanical seal shall be provided. Single-row, deep groove ball bearing contained in cartridge type bearing housing are to be pressed on the shaft at the outboard (thrust) and inboard (radial) areas. Bearing housings shall be positioned by means of dowel pins in the lower half casing.

The casing shall be dowelled, single volute and axially split along the shaft center-line. Flat face suction and discharge flanges are to be cast in the lower half casing. Flanges shall meet A.N.S.I. standards. Upper and lower casing shall be bolted together along with bearing housing caps and line bored to assure accurate bearing alignment. Bearing brackets are to be machined integral with the lower housing to maintain accurate and permanent shaft alignment. The upper half casing is to be tapped at the stuffing box area to provide

Wichita Department of Water

PUMPS - HIGH SERVICE

37th St BPS Specs

for sealing fluid. The lower half casing shall be provided with drain holes. Casing stuffing boxes shall also be designed to accept a single mechanical seal. Casing to be designed to allow for complete removal of the shaft assembly without disturbing piping or driver mounting. Pump mounting feet are to be cast integrally into the lower half casing. Suction and discharge gauge connection shall be provided on the nozzles. A tap at the high point of the upper half casing to be provided with petcock to serve as an air release or volute priming connection.

Wearing rings of the annular type, designed to minimize casing recirculation, are to be provided for both impeller and casing. Wearing rings shall be locked against rotation.

A fabricated structural steel base for pump and driver is to be supplied. The base shall be designed to resist torsional movement and support the combined weight of both pump and driver without deflection while at rest or under load. After alignment, the base shall be grouted in using openings provided in its top. A flexible coupling shall be supplied. An enclosed type coupling guard bolted to the base shall be provided.

D. MOTORS

A 460 volt, 3 phase, 60 Hz, horizontal TEFC motor shall be furnished with each pump. The motor nameplate rating plus service factor shall not be exceeded by the brake horsepower requirements of the pump for any condition of service for the impeller diameter installed. Maximum horsepower and RPM shall be as shown on the following data sheets.

E. NAMEPLATES

Each pump shall have a permanently attached metal nameplate with the Equipment No. as shown on the attached Pump Circulation Summary sheets engraved or etched in letters 1/2" high.

F. SPECIAL FEATURES

These features are required:

- 1. Impellers Bronze
- 2. Shaft Sleeves 13% Chromium Steel. Brinell 400.
- 3. Stuffing Boxes Bronze and Corrosion Resistant Bolts and Nuts
- 4. Gland Covers
- 5. Pumps must have Drip Boxes, Drain Openings, and Overflow Drains
- 6. Painting of inside of Pumps:
 - a. Forex 820 Primer
 - b. Forex 810 Heavy Chlorinated Rubber Paint 10 mils thickness

PUMP CALCULATION SUMMONTH ST BPS Specs

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n	TOTAL SUCT. PR.		th/sq.in.	Existing 24"	Water Main
24.	HFSH		الماءية والما		
73.	DISCH CONDITIONS	Hor-IlVeq.	in, Max-lb/sqin		
26.	LICHEAD .				
77.	PRAT EQUIP.	<u> </u>			7
ľ.	EXCH, PR. DROP				
77.	FURH.PR.DROP	ļ			
	CONT. PR. DROP	<u> </u>			
	LINE PR DROP	ļ			
	TOTAL DISCH.PR.	100			
: # T	TOTAL SUCT.PR.	56		Existing 24" Water Main	
1 7	DIFFERENTIAL	44			
7	Hyd.HE	200	$\frac{(x + 44)}{1714}$		
34. 37.	GPM X DIH	1	,		
	1714		5,1 HP 63 s		
	EST, EFFICIENCY EST, BHP	20 0X	8.2 * внр		
3 1	TYPE PUMP		t Case		7
Γ	TYPE DRIVER	15 HP T		Pumping Curve :	
\vdash	UTILITY CONS'P	47 144 1	<u> </u>	Shut off @ 104 Ft.	
	STEAM	نـوه/طا	*F	Operating 200 GPM @101 Ft.	_
	EXHAUST	ll⊾/sq.l		Maximum - 410 GPM @ 72 Ft.	-
1 F	ELECTRICITY		3 Ph: 60 Cycles		
	CASE	CI			
Ø.	IMPELLER	Steel			
8.	Shaft	Steel			•
	RPM		•		
	PACKING		•		•
	LIQUID CYL.				
	LIQUID ROOS .	 	<u> </u>	1	
23 प्र	PISTON SPEED		fi/min.		
_					PUMP
MDE	GM		POE & ASSOC	IATES - CONSULTING ENGINEERS	LCULATION
CHT	<u>. </u>	l	Wichita Depa	rtment of Water SU/	AMARY SHEET

37th Street Booster Station

REVISION DATE A

6-9-77

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PAGE 1110.00-3

CALCULATION SUMMARTH St BPS Specs EQUIP, NO. CHG. HO. 1146 JOS NO. PU-237th Street Water Booster Pump Station PLANT OR BLOG. TOTAL: 1 RUN: 1 SPARE: NO. UNITE Water Pressure SERVICE Booster Water WTL. PUMPED •API 1.0 API & Sp. Co. SOF AMB • OPER.TEMP. (T) VISCOSITY AT T IL/sq.in. ABS VP AT T -- He Sp Gr. # 8 ll√lu, NOR DUANTITY HORMAL GPM 500 a Q. (HATE : 500 x Sp Cr 400 e Doc T **GPM** 5, EXCESS CAPACITY **GPM** . Լ. * YTHTHAUD.XAU 5. X 2.31 NET LIQ.HEAD lb/sq.la. ON SUCTION INeg-la. PRAT EQUIP. Ildag.la. LINE PR DROP Existing 24" Water Main th/sq.in. TOTAL SUCT. PR. بطه منوه الطا HPSH Max-lb/sq in Nor-Ib/sq.in. DISCH. CONDITIONS CABHOL PRAT EQUIP. EXCH, PR. DROP FURN.PR.DROP CONT. PR.DROP LINE PR DROP 100 TOTAL DISCH.PR. 48 TOTAL SUCT.PR. DIFFERENTIAL 52 400 x 52 HILLE Existing 24" Water Main CPM X DIH 1714 60 EST. EFFICIENCY внР xxx 20.2 EST BHP Split Case TYPE PUMP 30 HP TEFC TYPE DRIVER Pumping Conditions: UTILITY CONS'P Shut off @ 120 Ft. STEAM Monain. Operating - 400 GPM @ 120 Ft. Ib/sq.in. EXHAUST Maximum - 800 GPM @ 70 Ft. 460 **v**: 3 Ph: 60 Cycles ELECTRICITY CASE Steel IMPELLER Steel SHAFF 1770 RPM PACKING LIQUID CYL. LIQUID ROOS Wmin. PISTON SPEED PUMP CONSULTING ENGINEERS POE & ASSOCIATES * GM CALCULATION SUMMARY SHEET Wichita Department of Water yr D' 37th Street Booster Station

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PAGE 1110-00-4

419

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6-9-77

REVISION DATE

UMP CALCULATION SUMMA 37th St BRS Specs

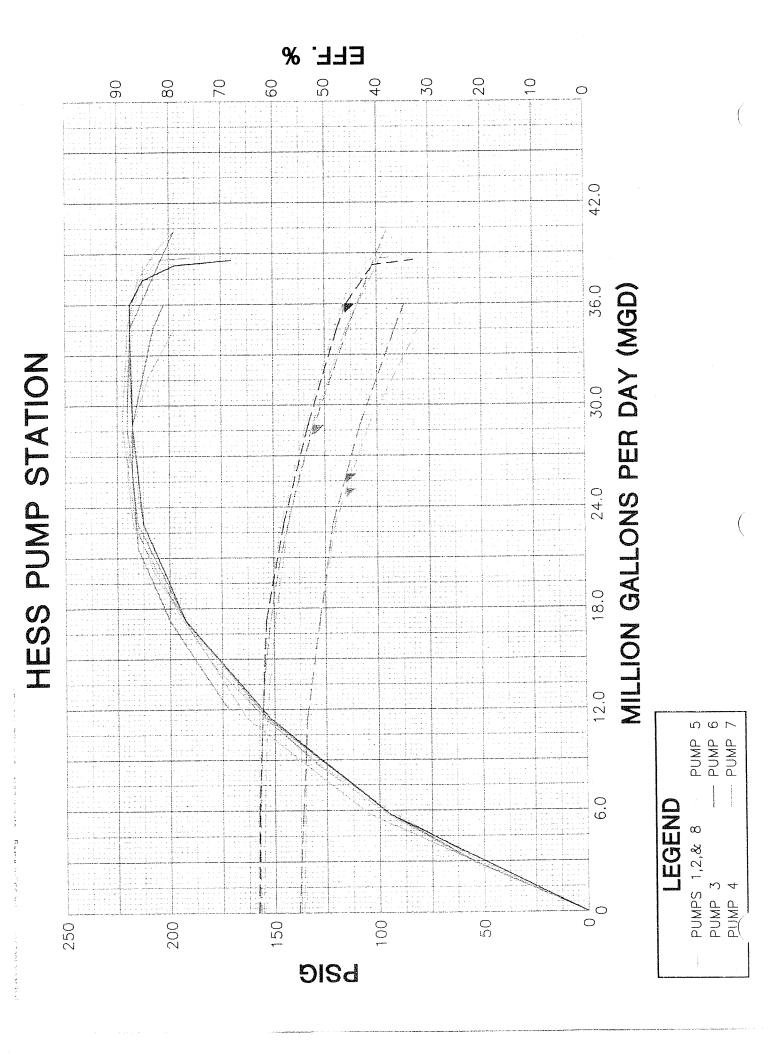
•	4		
1108 NO. 110	+6	Снс. но.	EQUIP. HO.
PLANT OR BLOG		Booster Pump Station	PU-3
NO. UNITS	TOTAL: 1 RUN: 1 SPARE:		
SERVICE	Water Pressure	·]	
1 31/4	Booster - Fire	·	
<u> </u>	•	_	,
NTL.PUMPED	Water		
#	*API 1.0	-1	
1 .P. & So G. 60°F	AMB *		
1 OPER.TEMP. (T)	Arm •	-	
N VISCOSITY AT T			
ABS VP AT T	mm Hg 15/14-19L	•	
0 Sp Gr. or T	11.4	-	•
I HOR QUANTITY	1b/hc	-{	
HORMAL GPM	\ \(\left(11 \lambda \lambda \cdot \frac{11 \lambda \lambda \cdot \frac{11 \lambda \lambda \cdot \frac{11 \lambda \cdot \cdot \cdot \frac{11 \lambda \cdot \cdot \cdot \cdot \cdot \frac{11 \lambda \cdot \		
1 111/2 : 500 a So C]		
= Oper.T	1500 _{GPM}	<u>.</u>	•
I EXCESS CAPACITY	\$	4	
WAX.QUANTITY	"L. GPM		•
NET LIQHEAD	h. X 1b/sq.in.		•
ON SUCTION	4.31		
PRATEQUIP.	Ib/sq-in-		
LINE PR DROP .	lb/sq.ln.	Existing	g 24 " Water Main
N TOTAL SUCT. PR.	16/sq.in.		
אניא א	!l√sq.in.Ab.	.]	
A DISCH CONDITIONS	Nor-la/sq.in. Mox-lb/sq in] .	
X LIGHEAD .			
PRAT EDUIP.	·		
A EXCH PR DROP] - (())	
N FURN.PR.DROP			
I CONT.PR.DROP			
LINE PR DROP] ./	
I TOTAL DISCH.PR.	100		•
I TOTAL SUCT.PR.	48] /	•
A DIFFERENTIAL	52 .] /	
ii e	/1500 x 52] /	
	(1000, 100) •		
СРЫ X DIH 2. 1714	45.5 HP	Existing 24" water Main	
EST. EFFICIENCY	76 s		
EST BHE	хох 59.9 вн Р		72
2 TYPE PUMP	Split Case] .	7
TYPE DRIVER	75 HP TEFC	1	
O UTILITY CONS'P		Pumping Conditions:	
STEAM	lb/sq.is. *F	· -	-
EXHAUST	IL/19.10. °F	Shut off @ 125 Ft.	
LECTRICITY	460v: 3 Ph: 60 Cycles	Operating - 1500 GPM @ 120 Ft.	
CASE	CI	Maximum - 2500 GPM @ 65 Ft.	
MPELLER	Steel	1	
SHAFT	Steel		•
RPM	1770		
PACKING	h /		•
LIQUID CYL.		1 .;	
LIQUID ROOS	· · · · · · · · · · · · · · · · · · ·		
PISTON SPEED	IVmia.	1	
AU SEFD	12 min		
W.	חחב פ גננחו	CIATES . CONSULTING ENGINEERS	PUMP
GM.	PUE & ASSUL	IATE - CONSULTING LITORITECIA	CALCULATION SUMMARY SHEET
W.Z.			SUMMARY SHEET

Wichita Department of Water 37 Street Booster Station

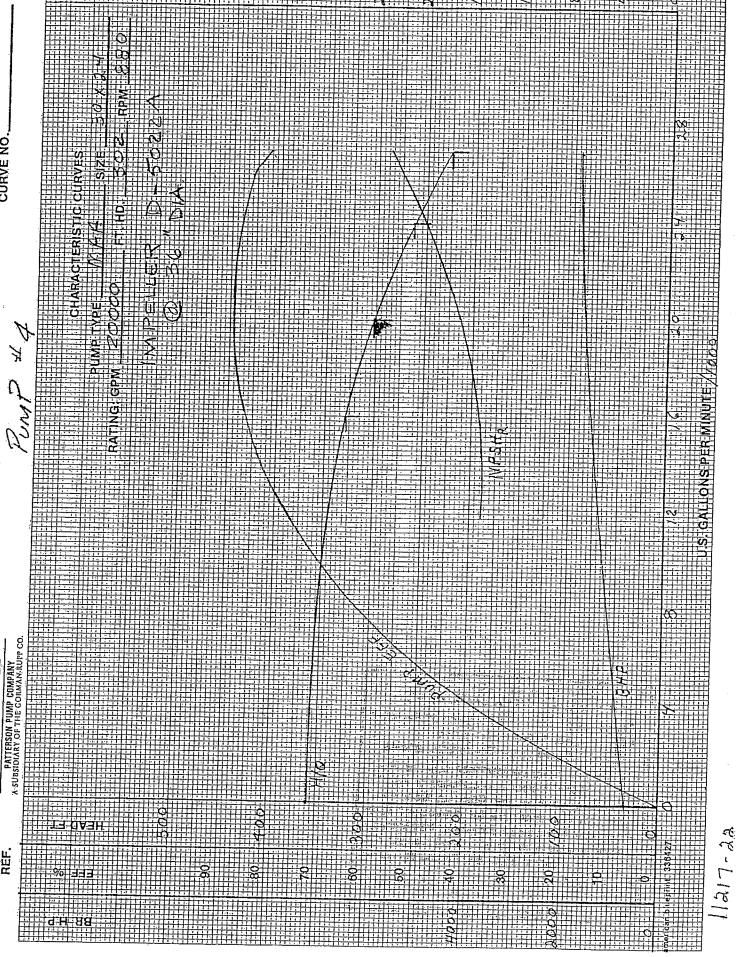
SEVINOH DATE

6-9-77

PAGE 1110.00-5



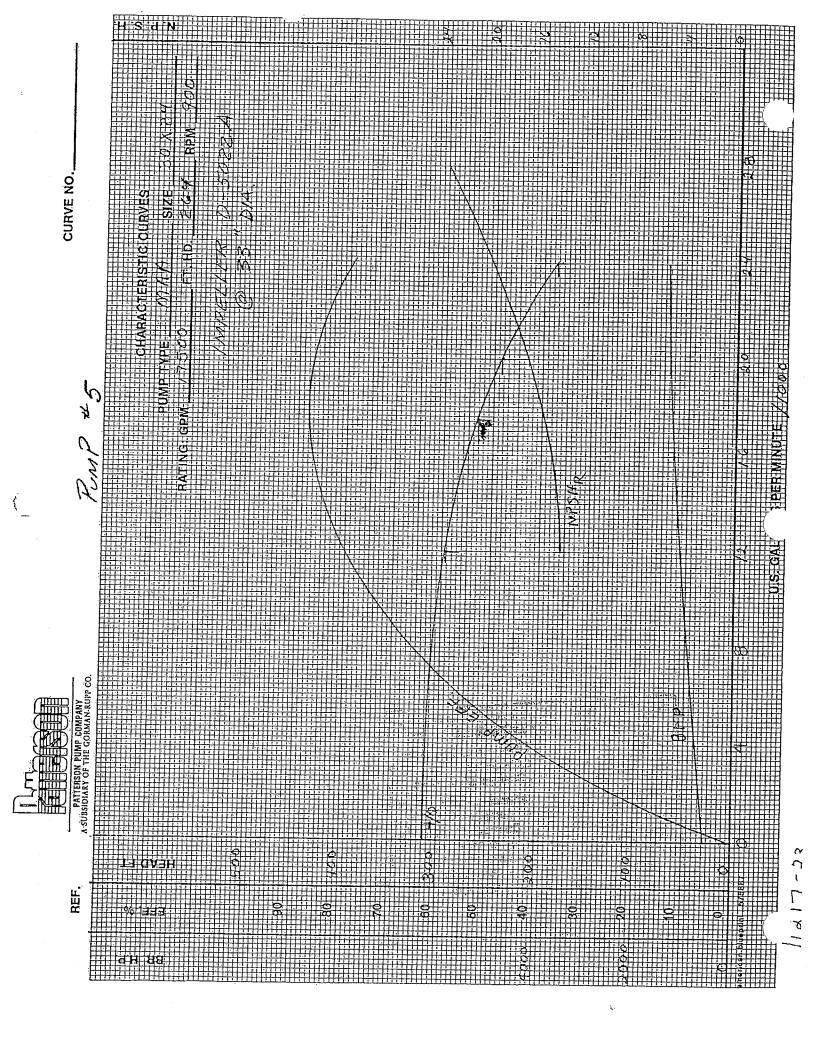
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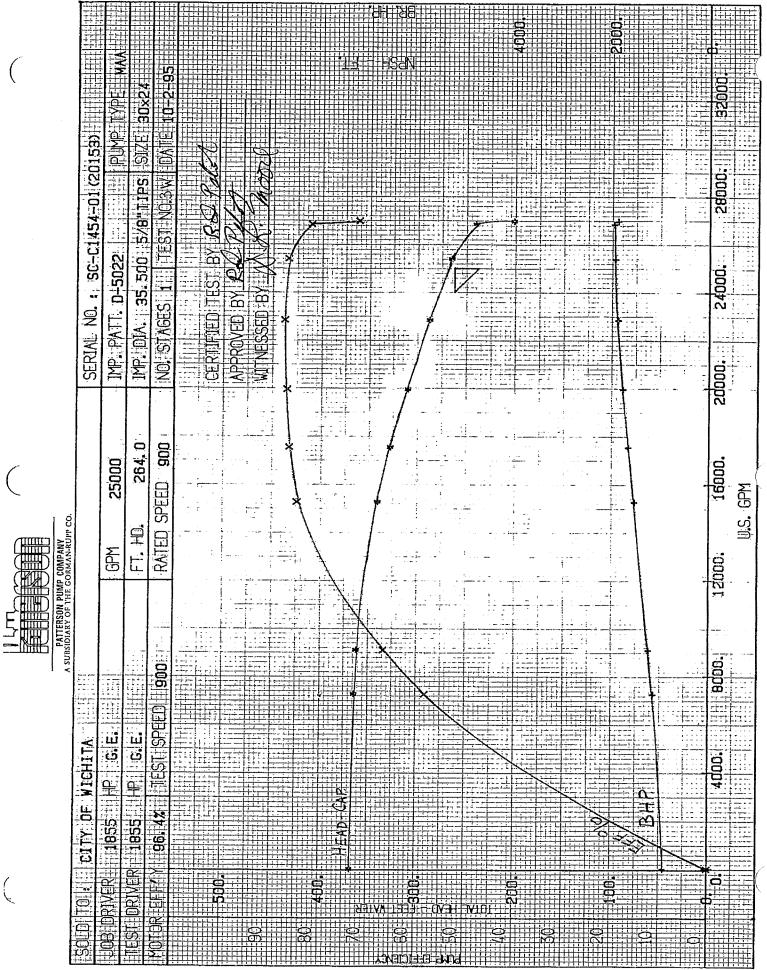
CURVE NO.

REF.

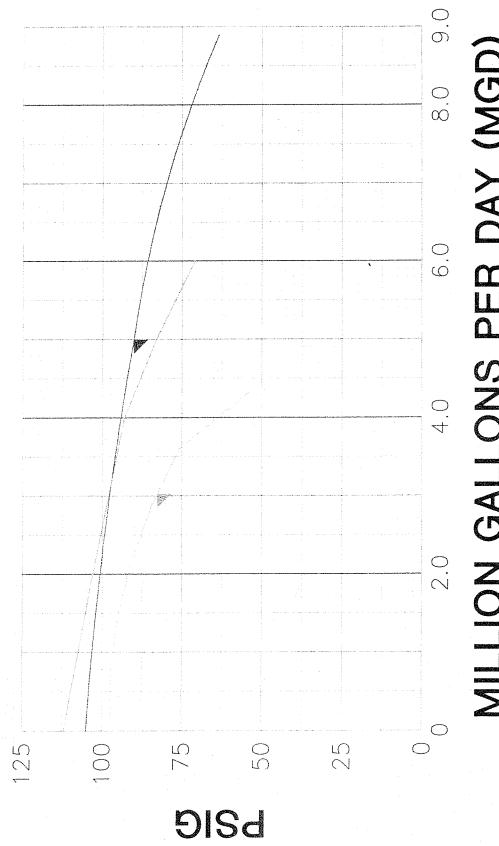
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Dans # 1 T. T. T. T.	17.1	100	1/2	NO. STAGES IT TEST NOTION DATE: HE SHOW	CERTIFIED TEST BY BY BY	APPROVED BY X & CALLY X	WINESSED BY XX XX (12 bx) 2	*			*										. 24000	
PATTERSON PUMP COMPANY A MUISIDIARY OF THE GORMANSHUPP CO.		GPM 25000	0	RATED SPEED 900		▼ • • • • • • • • • • • • • • • • • • •	M	Ximmon Ximmon X		+		<i>*</i>		•			•	The state of the s		į .	12000. 16000. 20000.	U.S. GPM
	DIVED CALL DE WICHING	TOTAL STATE OF THE		30,4% ES SULED					}			2 - 6 - 6	var.		3	7/	20		10 HINNISHR		4000;	



WEBB ROAD FUMP STATION



MILLON GALLONS PER DAY (MGD)

LEGEND

PUMP BDP-2 PUMP BDP-3 (PUMP MLP-1

AUG 05 2003 12:28 FR WATER TREATMENT PLAN#316 269 4750 TO 618168223414

P.08/09

PUMPING EQUIPMENT oject: WEBB ROAD, 5 MGD PUMP DY: CRAIG STEFFEN

H2Optimize ver. 5.03

File: (untitled) Jan 16, 19101

CURVE: PC120356B

PUMP DATA SHEET AURORA PUMP

Catalog: AURORA60 v. 1.2

TYPE - SPEED: 410-HSC - 1800

PUMP Size: 8x10x15B

Speed: 1750 rpm Imp dia: 15.375 in

Max Temperature: - °F

Max Pressure: - psig

Max Sphere Size: - in

Specific Speed Ns: -

Suction Nss: -

Suction size: 10 in Discharge size: 8 in

FLUID Water tmp: 60 °F

SG: 1

vsc: 1.122 cP

vapor. 0.2568 psi

atm: 14.7 psi

DI/MI 2001

BPS

WEBBROWD

NPSHa: - ft

250 HP

NO VFD

PIPING Pressure: - psi

size; - in

Discharge size: - in.

Suction elev: - ft

DESIGN POINT

Flow: 3475 gpm

Head: 192 ft

DATA POINT -

Flow: 3475 gpm

Head: 192 ft

Eff: 87 %

Power, 194 bhp

NPSHr. 19.8 ft

- DESIGN CURVE -

Shutoff Head: 259 ft

Pressure: 112 psig

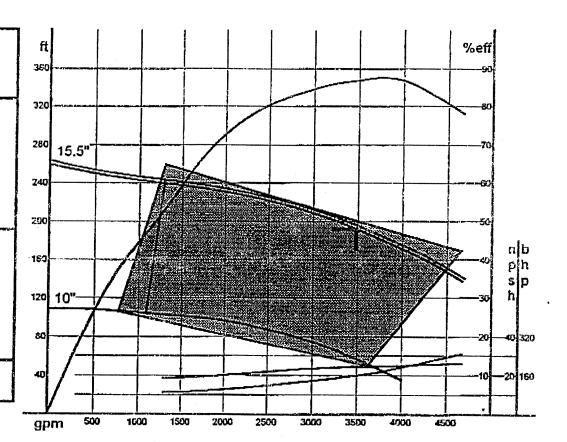
Min Flow: 1299 gpm

BEP: 38 %eff @ 3710

Max: 207 bhp @ 4666

- MAX DIAMETER -

Max: 213 bhp @ 4690



PERFORMANCE EVALUATION -

Flow gpm	Speed rpm	Head ft	Pump %eff	Power bhp	NPSHr ft	Motor %eff	Power kW	Hrs/yr	Cost
4170 3475 2780 7085 390	1750 1750 1750 1750 1750	163 192 212 227 238	85 87 81 72 56	202 194 184 166 149	25.8 19.8 16.4 13.4 11.3				

EP2

2001

150 HP

ASC PUMPING EQUIPMENT

Project: WEBB ROAD, 12.5 MGD PUMP

by: CRAIG STEFFEN

H2Optimize ver. 5.03

File: (untitled) Jan 16, 19101

CURVE: PC150836

PUMP DATA SHEET AURORA PUMP

Catalog: AURORA60 v. 1.2

YPE - SPEED; 410-HSC - 900

PUMP Size: 14x16x18

Speed: 885 rpm Imp dia: 16.9375 in

Max Temperature: - °F

Max Pressure: - psig Max Sphere Size: - in

Specific Speed Ns: -

Suction Nss: -

Suction size: 16 in Discharge size: 14 in ELLID Water tmp: 60 °F

SG: 1

WEBBROAD vsc: 1.122 cP BPS

vapor: 0.2568 psi atm: 14.7 psi

MZ M3

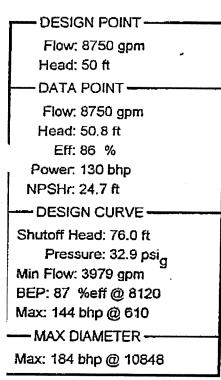
NPSHa: - ft

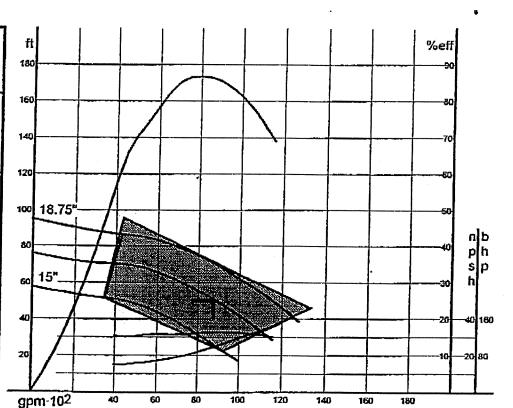
M4

PIPING Pressure: - psi Suction elev: - ft

size: - in

Discharge size: - in VFD





Flow gpm	Speed rpm	Head ft	Pump %eff	Power bhp	NPSHr ft	Motor %eff	Power kW	Hrs/yr	Cost
10500	885	37.3	77	129	31.5				
8750	885	50.8	86	130	24.7				
7000	885	60.8	85	126	19.0				
5250	885	67,7	72	125	16.0				
3500	Flow R	ate is Out	of Range	for this Pump			•		

Burns & McDonnell
SINCE 1898

S	I	N	С	Ε	1	8 9	8 (
 			-		-			_	

122199 Form GCO-28

Client	WIGHITA	}			_Page <i>l</i>	_ of\
Project	34007			Date \$/6/03	_Made By_JŁ	
	well	Rood	BOS	•	_Checked By	
					Proliminan	Final

	VFD			VFD	
	M3 M4	M1/01	D2	D3	
4 9	1 9 9				
	7 7 7				
		M	ML		
		NC	/\\(\)	r	
	\sim				

150 HP 250 HP 150 HP 300 HP 8750 gpm @50' 3475 gpm @ 192' 3500 gpm @ 210' 150 HB

EP2

2001 1982 2001 2100gpm@190' NEPZ

Larry Ward 316-337-9177 9178 (Mice)

Size : 410 - 8x10x15B

Stages :1

Service : 1 Based on curve number

: 60 Hz

: 1.231.6 USapm

: 002

Quantity : 14-8x10x15B-1775 Rev 11/15/12 Quote number : 183294 Date last saved : 18 Aug 2015 3:49 PM

Operating Conditions

: 3,000.0 USgpm Flow, rated Differential head / pressure, rated (requested) : 190.0 ft Differential head / pressure, rated (actual) : 189.8 ft Suction pressure, rated / max : 0.00 / 0.00 psi.g NPSH available, rated : Ample

Performance

Frequency

Item number

Speed, rated : 1,775 rpm Impeller diameter, rated : 14.44 in Impeller diameter, maximum : 15.50 in Impeller diameter, minimum : 10.00 in Efficiency : 83.45 % NPSH required / margin required : 17.74 / 0.00 ft ng (imp. eye flow) / S (imp. eye flow) : 44 / 202 Metric units

Head, maximum, rated diameter : 231.4 ft Head rise to shutoff : 21.94 % Flow, best eff. point (BEP) : 3,709.3 USgpm Flow ratio (rated / BEP) : 80.88 % Diameter ratio (rated / max) : 93.15 % Head ratio (rated dia / max dia) : 89.59 %

Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010] : 1.00 / 1.00 / 1.00 / 1.00 : Acceptable

Selection status

Minimum Continuous Stable Flow

Liquid Liquid type

Additional liquid description Solids diameter, max : 0.00 in

Solids concentration, by volume : 0.00 % Temperature, max : 68.00 deg F Fluid density, rated / max : 1.000 / 1.000 SG

: Water

PHONE: · FAX:

Viscosity, rated : 1.00 cP Vapor pressure, rated : 0.34 psi.a

Material

Material selected : Standard

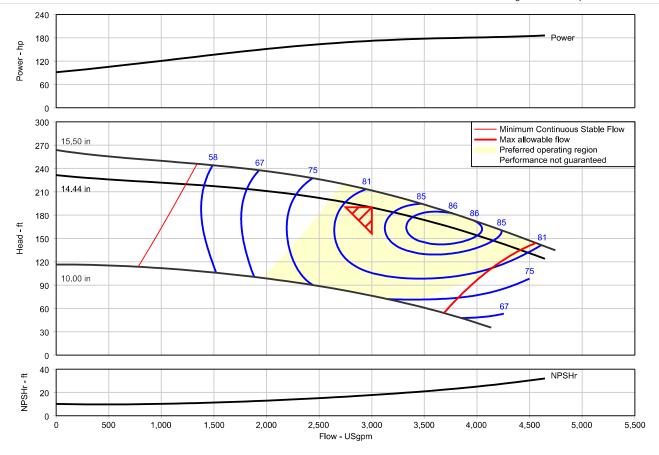
Pressure Data

Maximum working pressure : 100.1 psi.g Maximum allowable working pressure : 250.0 psi.g Maximum allowable suction pressure : 250.0 psi.g Hydrostatic test pressure : 125.0 psi.g

Driver & Power Data

Driver sizing specification : Max Power Margin over specification : 0.00 % Service factor : 1.00 Power, hydraulic : 144 hp Power, rated : 172 hp Power, maximum, rated diameter : 186 hp

: 200 hp / 149 kW Minimum recommended motor rating



Item number : Default Size : 410 - 10x12x15B Service Stages : 1

Quantity : 1 Based on curve number : 14-10x12x15B-1775 Rev 7/24/15

Quote number Date last saved : 14 Jun 2016 4:28 PM

: 1.00 / 1.00 / 1.00 / 1.00

Operating Conditions Liquid

Flow, rated : 4,800.0 USgpm Differential head / pressure, rated (requested) : 210.0 ft Differential head / pressure, rated (actual) : 211.6 ft Suction pressure, rated / max : 0.00 / 0.00 psi.g NPSH available, rated : Ample

: 60 Hz Frequency **Performance** Speed, rated : 1775 rpm Impeller diameter, rated : 15.00 in Impeller diameter, maximum : 15.00 in Impeller diameter, minimum : 12.00 in Efficiency : 85.77 % NPSH required / margin required : 17.23 / 0.00 ft ng (imp. eye flow) / S (imp. eye flow) : 51 / 262 Metric units Minimum Continuous Stable Flow : 1,695.9 USgpm Head, maximum, rated diameter : 256.1 ft Head rise to shutoff : 21.96 % Flow, best eff. point : 5,706.2 USgpm Flow ratio, rated / BEP : 84.12 % Diameter ratio (rated / max) : 100.00 % Head ratio (rated dia / max dia) : 99.23 %

Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]

Selection status

Liquid type : Water Additional liquid description

Solids diameter, max : 0.00 in Solids concentration, by volume : 0.00 % Temperature, max : 68.00 deg F Fluid density, rated / max : 1.000 / 1.000 SG

Viscosity, rated : 1.00 cP Vapor pressure, rated : 0.34 psi.a

Material

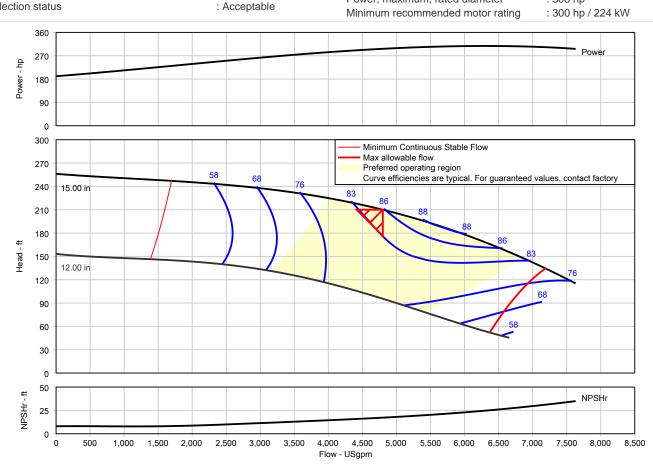
Material selected : Standard

Pressure Data

Maximum working pressure : 110.8 psi.g Maximum allowable working pressure : 250.0 psi.g Maximum allowable suction pressure : 250.0 psi.g Hydrostatic test pressure : 136.3 psi.g

Driver & Power Data

Driver sizing specification : Max Power Margin over specification : 0.00 % Service factor : 1.15 (used) Power, hydraulic : 254 hp Power, rated : 297 hp Power, maximum, rated diameter : 308 hp

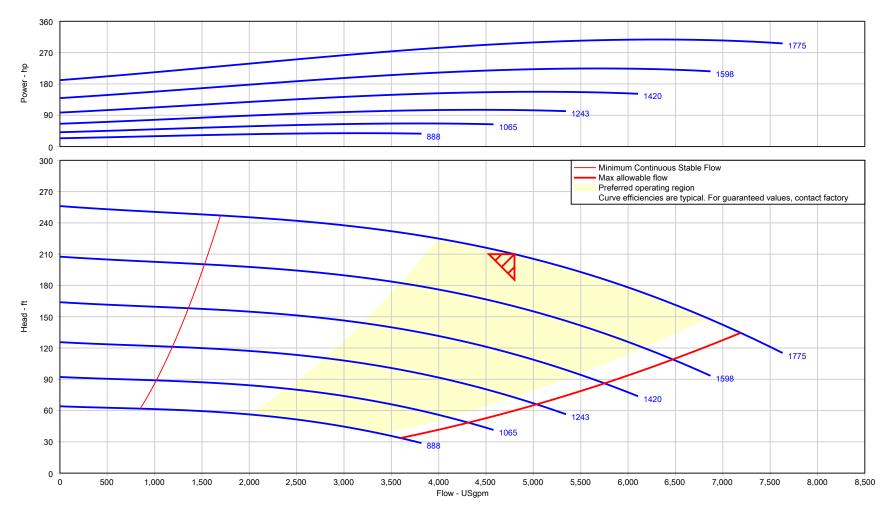




WWW.AURORAPUMP.COM







 Item number
 : Default
 Size
 : 410 - 10x12x15B
 Flow, rated

 Service
 : Stages
 : 1
 Differential head / pressure, rated

 Quantity
 : 1
 Speed, rated
 : 1775 rpm
 NPSH required

 Quantity
 : 1
 Speed, rated
 : 1775 rpm
 NPSH required
 : 17.23 ft

 Quote number
 : 14-10x12x15B-1775 Rev
 Fluid density, rated / max
 : 1.000 / 1.000 SG

Date last saved : 14 Jun 2016 4:28 PM 7/24/15 Viscosity : 1.00 cP

Efficiency : 85.77 % Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010] : 1.00 / 1.00 / 1.00 / 1.00 Power, rated : 297 hp Impeller diameter, rated : 15.00 in

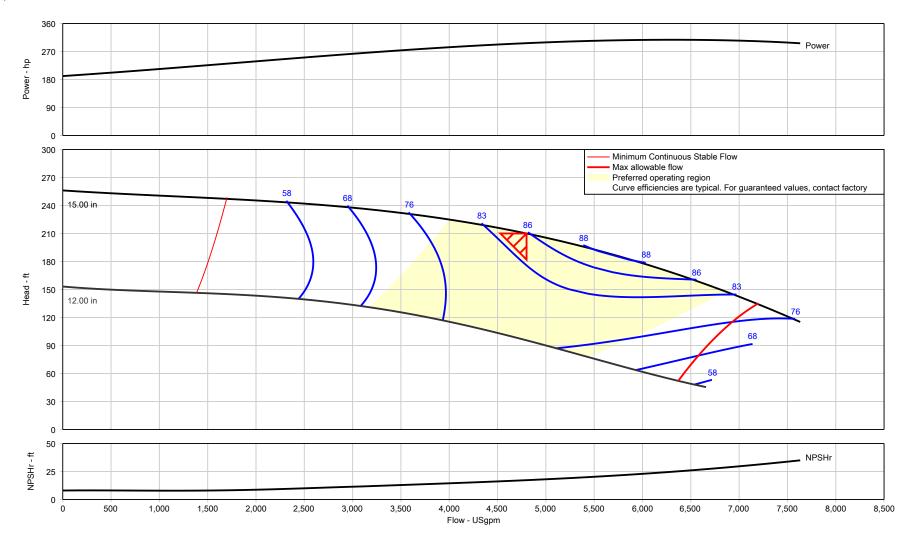


: 4,800.0 USgpm

: 210.0 ft

Encompass 2.0 - 16.2.3.0





: 410 - 10x12x15B : 4,800.0 USgpm Item number : Default Size Flow, rated

Service Differential head / pressure, rated Stages : 1 : 210.0 ft Quantity : 1 Speed, rated : 1775 rpm NPSH required : 17.23 ft

Based on curve number : 14-10x12x15B-1775 Rev Quote number Fluid density, rated / max : 1.000 / 1.000 SG Date last saved : 14 Jun 2016 4:28 PM

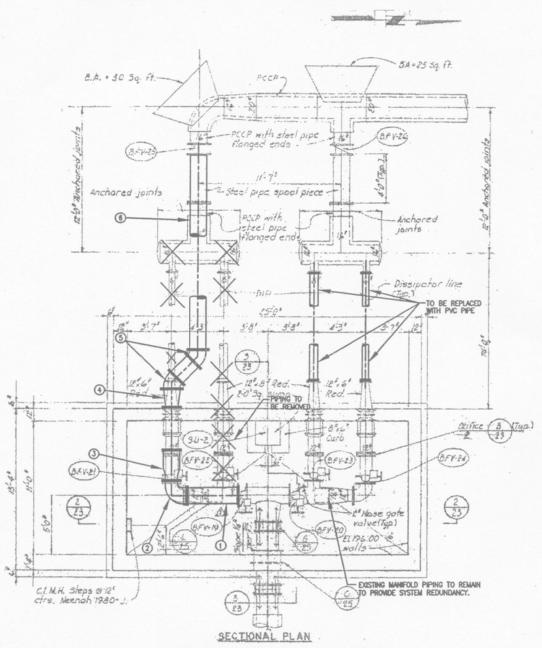
7/24/15 Viscosity : 1.00 cP

: 85.77 % Efficiency Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010] : 1.00 / 1.00 / 1.00 / 1.00 Power, rated : 297 hp



Webb Reservoir Sleeve Valve

WILSON & COMPANY BASE PROPOSAL



MANIFOLD VALVE STRUCTURE

NOTES:

16" SPOOL

2 16"x12" REDUCING 90"

12" SLEEVE VALVE

4) 12x16 RED. WITH RESTRAINED MJ

16" 45" BEND WITH RESTRAINED MJ

16" PVC PIPE

SYSTEM MANIFOLD REVISIONS ASSUMED DESIGN CRITERIA

MAX. DESIGN FLOW: 6950 apm (10MGD)
MAX. MANIFOLD INLET PRESSURE: 60 psi
VELOCITY IN 16* PIPE @ MAX. DESIGN FLOW: 11.87 fps
VELOCITY IN 12* PIPE FITTINGS @ MAX. DESIGN FLOW: 18.58 fps

Webb Reservoir S



ECN:

CMB industries, inc.

A United Dominion Company Fluid Control Division

P.O. Box 8070 Freeno, CA 93747-8070 1550 North Peach Fresno, CA 93727 Ph:(209) 252-0791 Fex: (209) 453-9030



Engineering Specification

Part No90086090 Rev. B-CD-86090

Certified Submittal Data Sheet and Certificate of Compliance

PREP. BY: bp APPD BY:

DATE: 1/30/02 DATE:

Page 1

CUSTOMER DATA/INFORMATION

Customer:

Wildcat Cont. Co 4421 West Harry

Wichita, KS 67277

Customer P.O.

6791-2317

PROJECT SPECIFIC DATA/INFORMATION

Job Name:

Webb Road P.S.

Engrg Firm:

12" Class 150

Proj. Engr.:

Valve Desc.:

Sleeve Valve

SLEEVE VALVE PRODUCT DATA/INFORMATION

Valve Size:

12"

Catalog No.:

305 Inlet Flange & Outlet Flange Manufacturer: SPX Valves & Controls

End Conn.:

150psi

Design W. P.: Assembly Dwg.:

D4410

SLEEVE VALVE PRODUCT OPERATOR DETAILS/DATA

Type:

Limitorque Electric Motor Operator

Model:

L120-20

Voltage: 208VAC/3PH/60HZ with VFD

Wiring Diagram: Outline Drawing: 03-612-0004-1

14-499-0001

Opening Time:

3.66 MIN

VALVE PAINT/COATING DETAILS

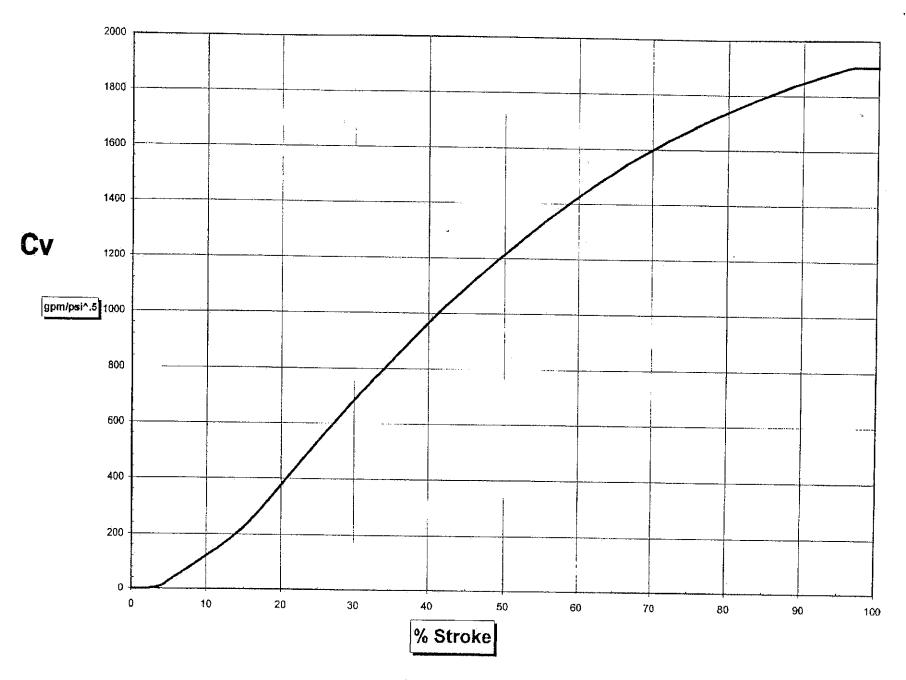
Valve Exterior: Valve Interior:

Fusion Epoxy - 10 Mils Morton Int'l Corvel Gray. Fusion Epoxy - 10 Mils Morton Int'i Corvel Gray.

This submittal has been prepared in accordance with the contract documents, except as

noted below:

END OF SECTION



Bill of Material 90086090 Sales Order B86090

	~PARTS	LIST	~
ITEM	DESCRIPTION	QTY	MATERIAL
1	BODY	1	DUCTILE IRON
1.1	PIPE PLUG	4	STEEL
2	SEAT RING	1	STAIN STEEL
3	O-RING	1	BUNA-N
4	SLEEVE	1	STAIN STEEL
5	SEAT HOLDER	1	STAIN STEEL
6	SEAT SEAL	1	BUNA-N
8	PISTON LINER	1	BRONZE
9	POLYPAK SEAL	1	MOLYTHANE
11	CYLINDER	1	STAIN STEEL
12	O-RING	2	BUNA-N
14	STEM HOUSING	1	STEEL
15	STUD	• 20	STEEL
15.1	NUT	• 20	STEEL
15.2	WASHER-FLAT	• 18	STEEL
15.3	LIFT STRAP	2	STEEL
22	CAPSCREW-DRILLED	12	STAIN STEEL
22.1	WASHER-FLAT	12	STAIN STEEL
24	CAPSCREW-DRILLED	12	STAIN STEEL
25	CAPSCREW	12	STAIN STEEL
35	STEM	1	STAIN STEEL
40	O-RING	1	BUNA-N
41	PIN	1	YLLW BRASS
42	GLAND	1	PHOS BRZ
43	STUD	4	STAIN STEEL
43.1	NUT	4	STAIN STEEL
44	STUFFING BOX	1	BRONZE
45	CAPSCREW-DRILLED	4	STAIN STEEL
46	O-RING	1	BUNA-N
47	PACKING	1	GARLOCK #432
52	KEY	1	BRASS
53	LUBE FITTING	1	-
54	CAPSCREW	2	STAIN STEEL
55	CAPSCREW	4	STEEL
57	OPERATOR	1	
58	STEM NUT	1	BRONZE
59	STEM COVER	1	STEEL

^{*} QUANTITIES ARE FOR A 12" MODEL

Valve	Flange			Dime	nsions	in inc	hes			Est
Size	Class	Α	В	C	D	E	F	G	Н	Wt.
10"	150# FF 300# FF	38.38	1.19	23.19	57.25	8.00	12	1.00	14.25	1,200
10	300# FF	39.75	1.88	22.50	57.25	8.75	16	1.13	15.25	1,280
	150# FF									
12	300# FF	48.00	2.00	24.00	60.30	10.25	16	1.25	17.75	1,450

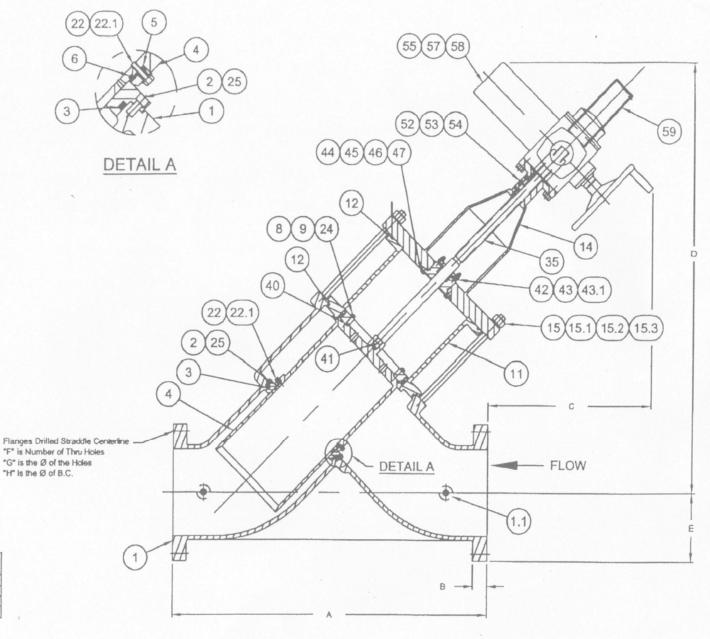
NOTES:

- 1. TEMPERATURE RANGE: 32°F-100°F
- 2. MAXIMUM WORKING PRESSURE IS: 250 psig Class 150 Flanges 600 psig - Class 300 Flanges.

Webb Reservoir Sleeve Valve

PROPERTY OF CHE NOUGHEST AND YOUNG TOWHISTITY CONCILLY OF CASE ADMITTMEST NEW COMPANY
WHISTITY CONCILLY OF CASE ADMITTMEST NEW COMPANY
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CHEMICA



UNLESS OTHERWISE SPECIFIED	
ALL DIMENSIONS IN INCHES.	7
CHANGER THREADS, BREAK ALL SHARP EDGES, RESHOVE ALL BURRIS, FLACH, ETC.	
TOLEPHACES.	C
# .OE CHI ALL JOX SEMENBORES	В
SHOKENING YOU, IJA NO 880. +	-
# 23, CM VIT WHOTER	A
ANSTRUMP DIVING DIAMETERS	-

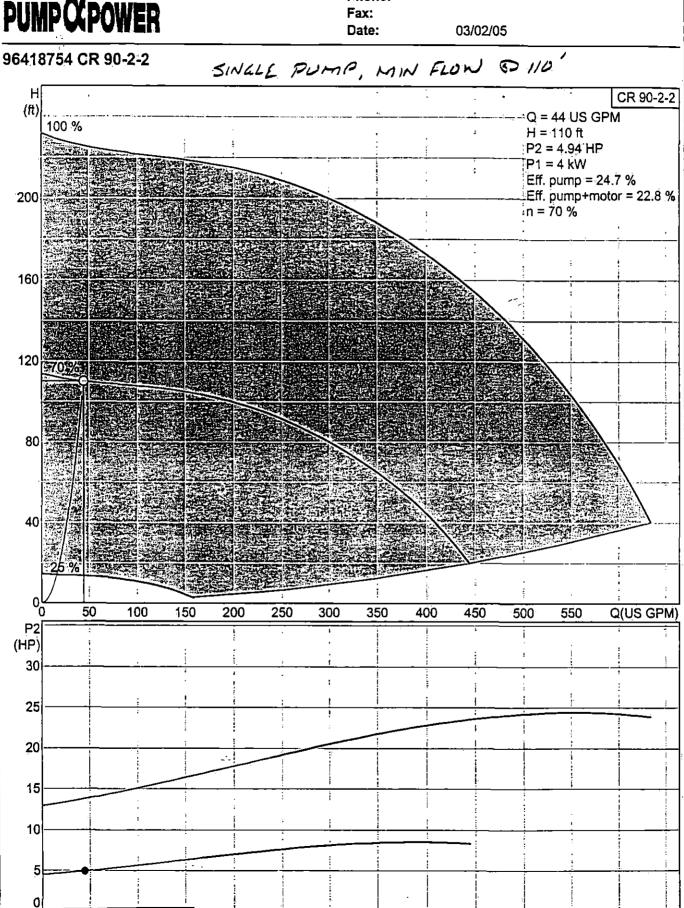
					AART N		POLYJET	#305 12 & 10°
С	3081	JM	JE	REVISED DWG FOR UPDATED REVISION	MA TEMB		NOTED	- MITEM NO
8	2001 84-11	вы	JE	Added 10" Class 150 to Table	P	1 800 I		PARTERN OWN NO
A	1968 06-19	ВМ	JE	Added Table	Switz In	-6	POLY	DRAWING NO
B'v.	DATE	Bt	A)-PPE	AEVISIO+		tre .	Chill Instantion, A United Sundryon Campany	C 4410

PUMP & POWER

West Maple BPS Company name:

Created by:

Phone:





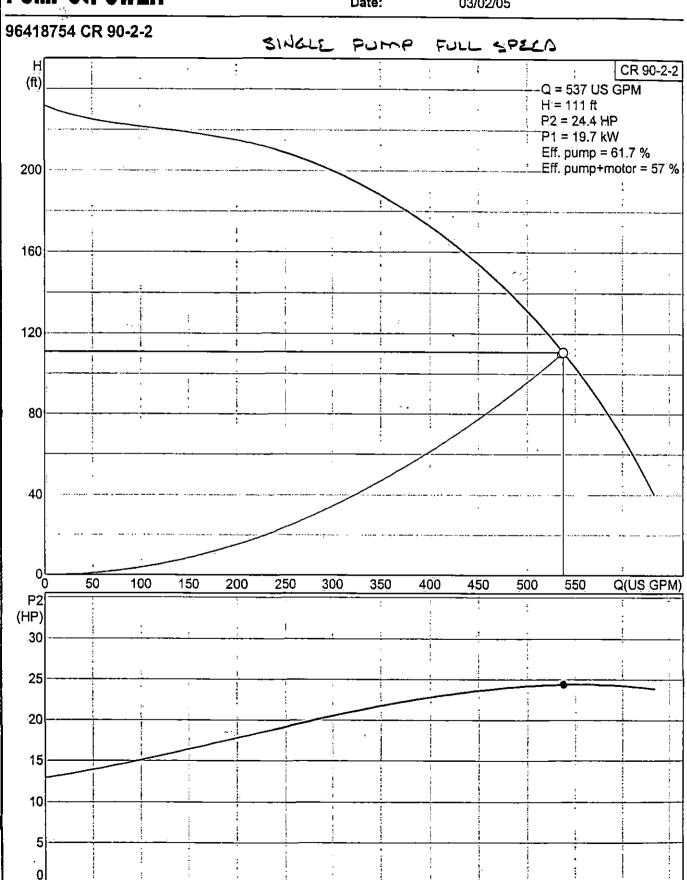
Company name:

Created by:

Phone: Fax:

Date:

03/02/05

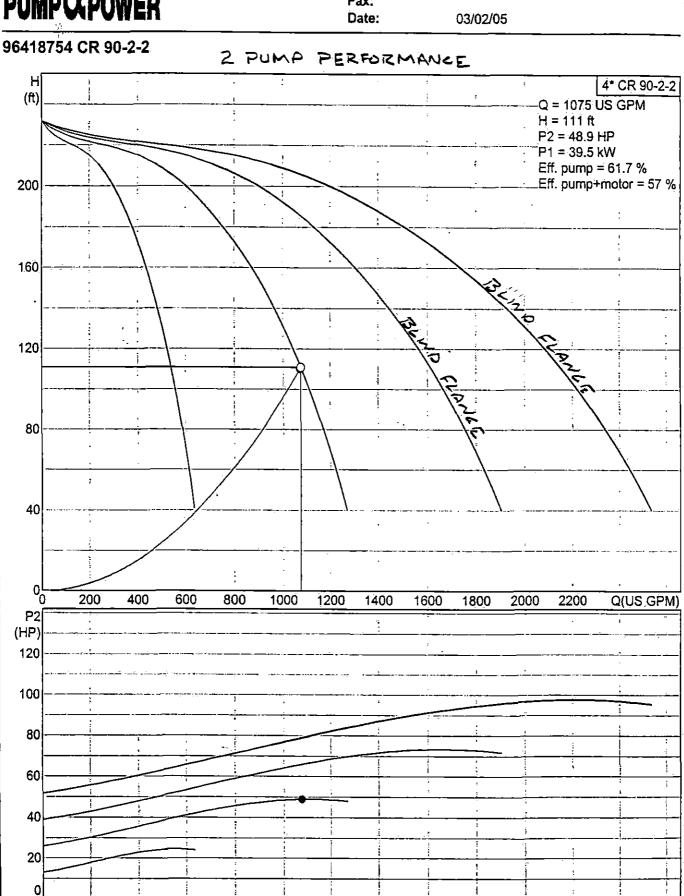


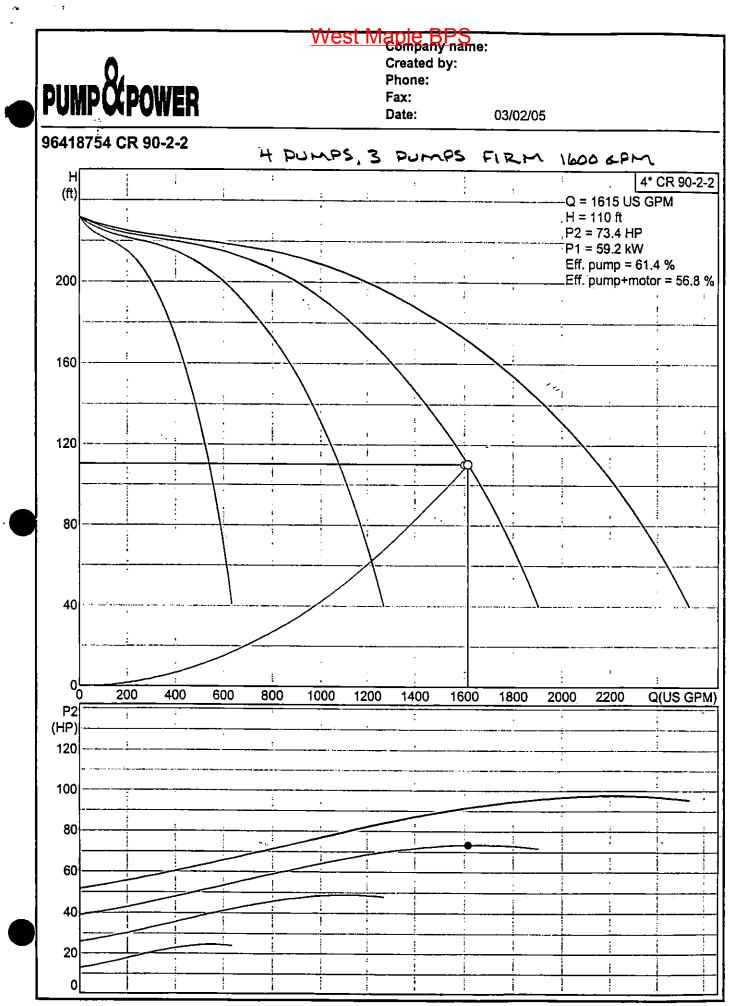


West Maple BPS name:

Created by: Phone:

Pnone





West Maple BPS

RECEIVED

OCT 2 1 2005

GRUNDFOS PUMPS

MANUFACTURING CORPORATION

October 14, 2005

ATTN: Pump & Power Equipment

9010 Rosehill Road Lenexa, KS 66215

RE:

VERIFIED PERFORMANCE TEST

GRUNDEOS PUMPS CORPORATION

P.O. # 168320-A

GRUNDFOS ORDER NO. 671299848

Enclosed you will find the requested VERIFIED performance test data for

Verified performance	Grundfos Pump	Pump Product
Test No.	Model No:	No.:
05-10-12	ME:4/2CR90-2-2 25HP 3X460V PMU	91135278 SERIAL # 1668

If you have any questions, feel free to contact the Grundfos BoosterpaQ Department.

Kind Regards,

Greg Bashian

Product Engineer

VERIFIED TEST NUMBER: SYSTEM DESCRIPTION:

51012 <u>VVest | VIIIE | 9</u>|| 20 RSD-2 25HP 3X460V PMU

Flow GPM	20.2	140	280	420	560	700	840	980	1080	1260
				NT OPERATI						
َر (In/Hg)	2.0	2.5	2.5	2.5	2.5	3.0	3.2	3.8	4.5	
Discharge (PSIG)	64	64	64	64	64	64	62	45	30	
Differential ft/h	148.8	149.1	149.1	149.1	149.1	149.3	144.8	105.8	71.5	0.0
Current (Amps)	0.1	11.5	14.9	26.2	33.5	45.4	55.6	57.5	57.1	0.0
Voltage (Volts)	456	455	455	455	455	455	454	455	454	
			MAX RU	N OPERATIO	ON					
inlet (In/Hg)	2.5	2.5	2.5	3.0	3.0	3.2	3.5	4.0	4.5	i -
Discharge (PSIG)	100	94	90	86	80	73	62	46	25	
Differential ft-Hd	232.2	218.4	209.1	200.1	186.3	169.0	144.9	108.2	60.0	0.0
Current (Amps)	28.7	33.0	37.5	41.6	47.9	53.4	56.3	58.1	57.3	0.0
Voltage (Volts)	456	455	455	455	455	455	454	455	454	

Customer Name	Pump & Power	<u>Enclo</u> sure	Nema 3R / IP54
Customer No.	600002908	Volts	480V
Customer P.O. No.	M07666	Amps	139
Grundros Order No.	671299848	S.F. Amps	
Date Code	541	\$.F.	
Grundfos Co.	GMU		
Product No.	91135278		· ·
Senal No.	1668		

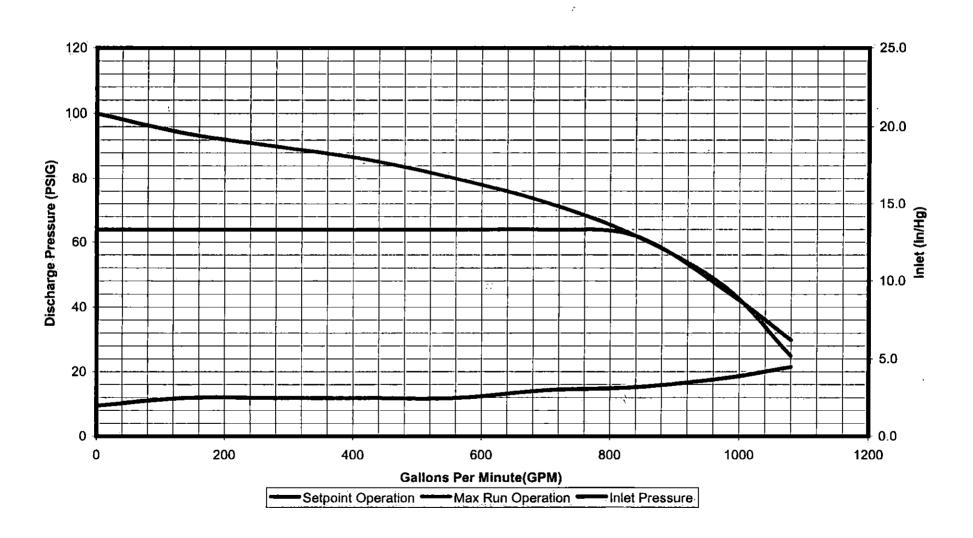
	SE							
	5.5 19 (37)	ີ່ຂໍ≱L2 ໍ້.	₹.L3\;		L2 :	33 L334		
:0	0.1			28.7				
140	11.5			33				
280	14.9			37.5				
420	26.2			41.6				
560	33.5			47.9				
700	45.4			53.4				
840	55.6			56.3				
980	57.5			58.1				
1080	57.1			57,3				
1260								

Testing Notes-

Cavitation occurred beyond 1080gpm - Limitation of test fixture

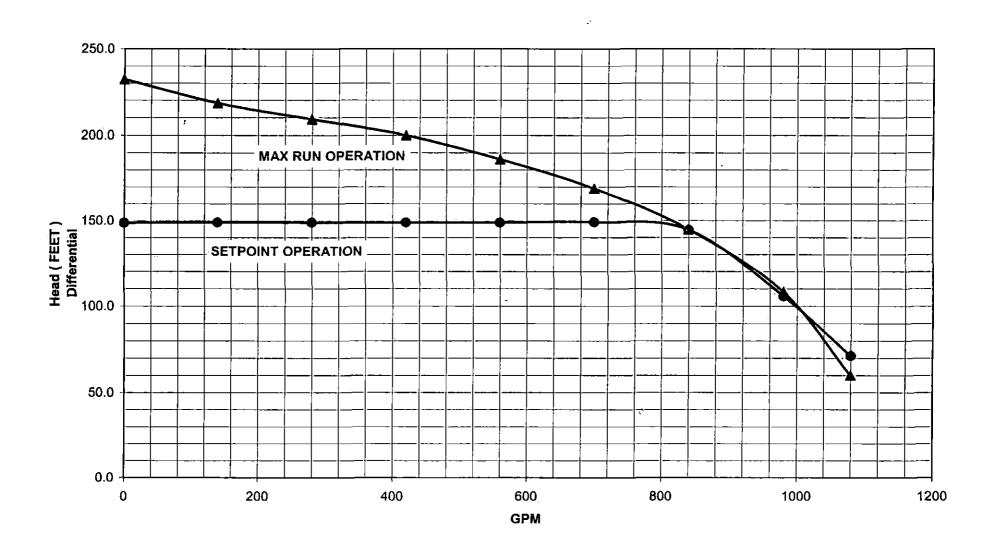


Verified Performance Test Discharge Pressure Versus Flowrate





Verified Performance Test Differential Pressure Versus Flowrate

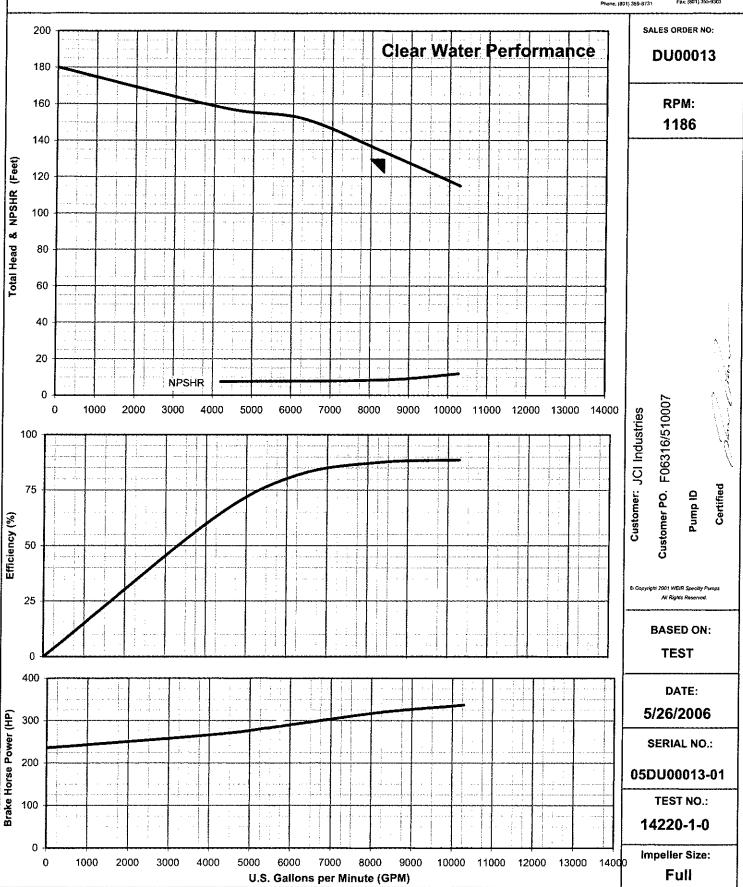


SEBPSoutheast BPS Pumps

WEMCO PUMP SDM 400/600HP



440 W. 800 S. Salt Lake City, Utah 84110 Fax: (801) 365-9303



Southeast BPS Pumps

WEIR SPECIALTY PUMPS

SUCTION	PIPING (in)	
ITEM	Nom. Diam Equiv Leng	132
elbow LR	0 0	132
elbow SR	0 0	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	24 24	132
pipe 2	0 0	132
gage corr.	* 22	

DATE:*	5/25/2006
PUMP TYPE:*	UNI GLIDE
MODEL NUMBER:*	UNI GLIDE 24X16
SERIAL NUMBER:*	05DU00013-01
PUMP TAG NO:	N/A
IMPELLER TRIM:	FULL
JOB NUMBER:*	DU00013
BUYER:	JCI INDUSTRIES
P. O. NUMBER:	F06316/510007
TEST BY:*	MATT

DISCHARGE PIPING (in)							
ITEM	Nom. Diam Equiv Leng	С					
elbow LR	16 26	132					
elbow SR	16 26	132					
sud.exp.1	0 0	132					
sud.exp.2	0 0	132					
pipe 1*	16 16	132					
pipe 2	0 0	132					
gage corr.	* 22						

CUSTOMER FLOW REQUIREMENTS										
Cond. Pt. GPM TH RPM Eff										
1	8330	130	1190	89						
2										
3				0.6 0.6						
4										

INSTRUM	ENT DATA
FLOW#:	3933
D-PSI#:	3955
S-PSI#:	3926
KW #:	2684
RPM#:	2688

	CUSTOMER MOTOR									
		HP SIZE:	350	VOLTS 460						
ITEM	0/4 LOAD	1/4 LOAD	2/4 LOAD	3/4 LOAD 4/4 LOAD 5/4 LOAI						
efficiency:	0.001									
corr.%eff:	0.001	And the first professional and the second se	in a marchine and in a marchine and a marchine profit to the profit of the second seco	надом в вереня 1 домарат и до дости в достава и сел до 4 или и дости сып выпуский основник, и подом до и объе в Надом						
	watt sca	ale factor:=	1	v-belt%eff. 1						

COMMENTS: 24" flow meter

PUMP PERFORMANCE @ 68°F

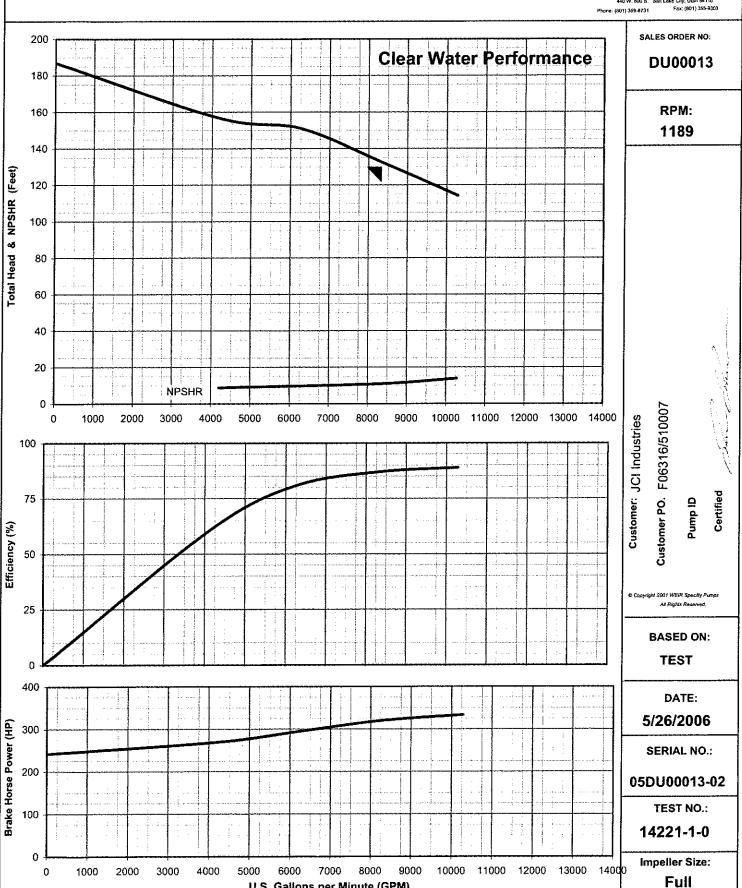
POINT NUMBER	water temp. `F	discharge pressure PSI	suction pressure PSI	Average Amps	PUMP SPEED (RPM)	FLOW RATE (GPM)	TOTAL HEAD (FEET)	CLEAR WATER HORSE- POWER	PUMP EFF.
1	68.0	87.0	9.0	285.0	1189.9	0.0	(180.1/	235.5	0.0%
2	67.8	76.8	9.0	316.0	1188.5	4203.6	158.0	268.1	62.6%
3	67.5	73.4	8.9	342.0	1187.2	6255.9	152.0	293.7	81.8%
4	67.9	64.5	8.8	385.0	1186.4	8330.1	133.6	320.8	87.6%
5	67.5	55.0	8.5	368.0	1185.7	10283.6	115.0	337.0	88.6%

Southeast BPS Pumps

WEMCO PUMP SDM 400/600HP



440 W. 800 S. Salt Lake City, Utah 84110 (801) 359-8731 Fax: (801) 355-9303 Phone: (801) 369-8731



U.S. Gallons per Minute (GPM)

Southeast BPS Pumps

WEIR SPECIALTY PUMPS

SUCTION	PIPING (in)	
ITEM	Nom. Diam Equiv Lenç	132
elbow LR	0 0	132
elbow SR	0 0	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	24 24	132
pipe 2	0 0	132
gage corr.	* 22	

DATE:*	5/25/2006
PUMP TYPE:*	UNI GLIDE
MODEL NUMBER:*	UNI GLIDE 24X16
SERIAL NUMBER:*	05DU00013-02
PUMP TAG NO:	N/A
IMPELLER TRIM:	FULL
JOB NUMBER:*	DU00013
BUYER:	JCHNDUSTRIES
P. O. NUMBER:	F06316/510007
TEST BY:*	MATT

DISCH	IARGE PIPING (in)	
ITEM	Nom. Diam Equiv Leng	С
elbow LR	16 26	132
elbow SR	16 26	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	16 16	132
pipe 2	0 0	132
gage corr	.* 22	

CUSTOMER FLOW REQUIREMENTS								
Cond. Pt.	GPM	TH	RPM	Eff				
1	8330	130	1190	89				
2								
3								
4								

INSTRUMENT DATA						
FLOW#:	3933					
D-PSI#:	3955					
S-PSI#:	3926					
KW #:	2684					
RPM#:	2688					

			CUSTOMER	MOTOR		
		HP SIZE:	350	VOLTS	460	
ITEM	0/4 LOAD	1/4 LOAD	2/4 LOAD	3/4 LOAD	4/4 LOAE	5/4 LOAD
efficiency:	0.001					
corr.%eff:	0.001		- et reumsveuw streichter storithreide hild in hill die Storitike	n.		22000000202044006
	watt sc	ale factor:=	1		v-belt%eff.	

COMMENTS: 24" flow meter

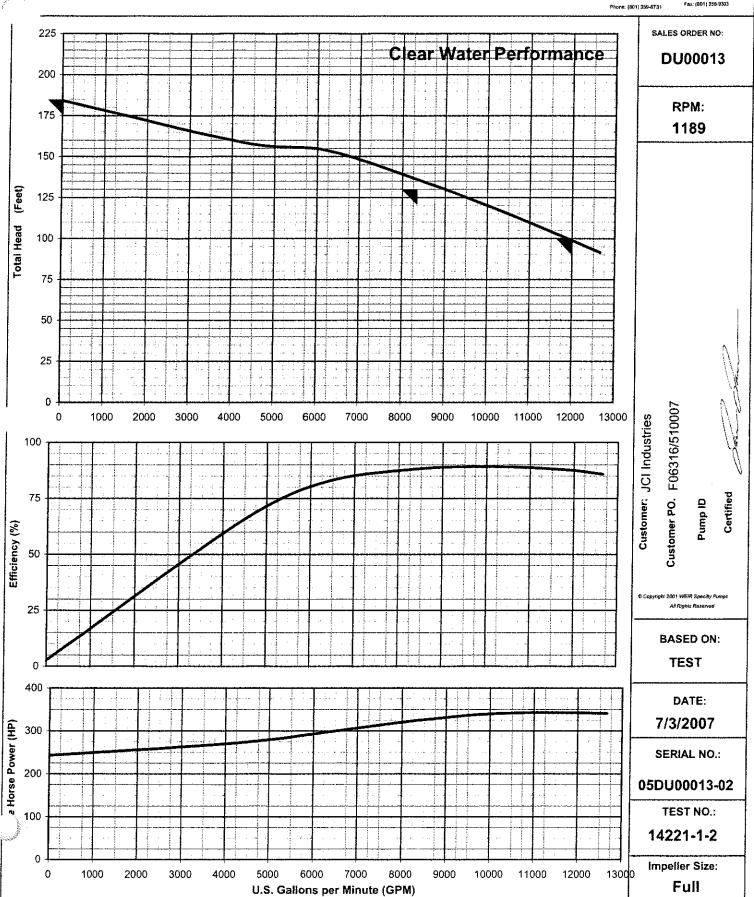
PUMP PERFORMANCE @ 68°F

POINT NUMBER	water temp. `F	discharge pressure PSI	suction pressure PSI	Average AMPS	PUMP SPEED (RPM)	FLOW RATE (GPM)	TOTAL HEAD (FEET)	CLEAR WATER HORSE- POWER	PUMP EFF. (%)
1	71.4	88.3	7.3	-75.4	1191.8	1.1	(187.0)	242.1	0.0%
2	71.2	74.6	7.4	-75.4	1191.8	4204.8	156.6	269.4	61.7%
3	71.4	71.4	7.3	-75.4	1189.9	6255.1	151.1	295.3	80.8%
4	71.5	62.4	7.2	-75.4	1189.5	8332.0	132.7	320.7	87.0%
5	71.4	53.1	6.9	-75.4	1188.8	10283.6	114.2	333.6	88.9%

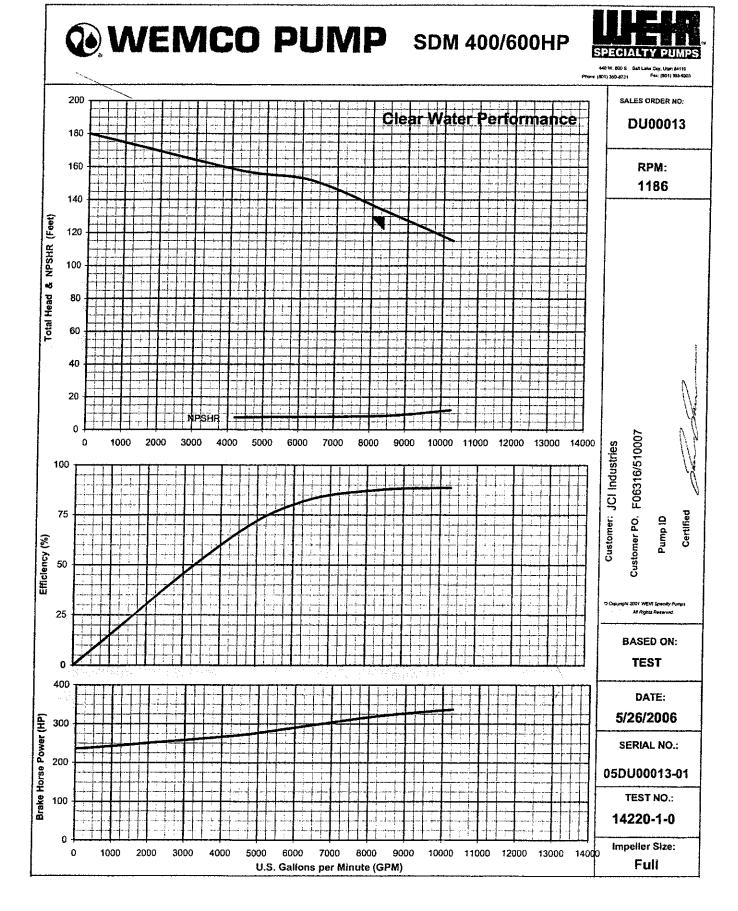
WEMCO PUMP SDM 400/600HP



440 W. 800 S. Satt Lake City, Utah 84110 Fax: (801) 355-9303



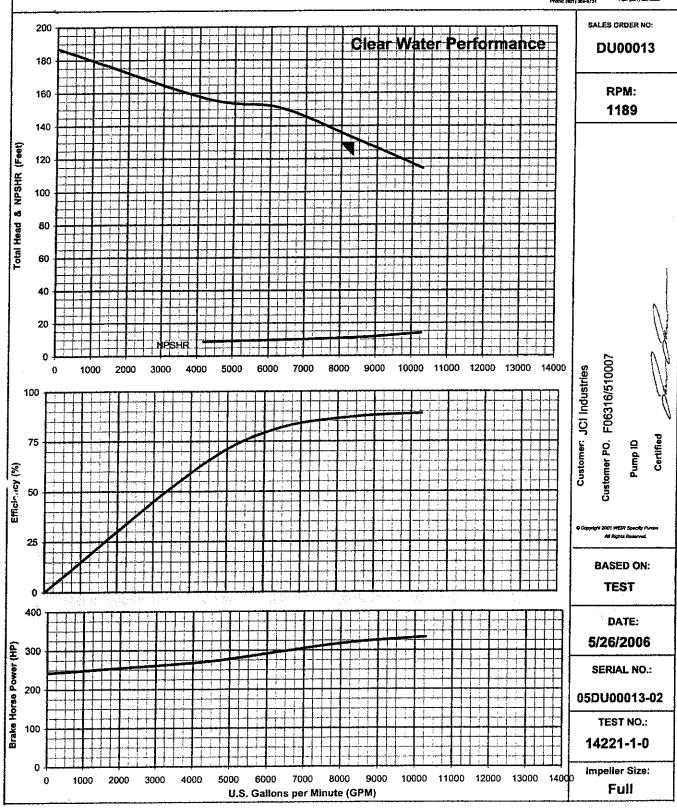
Southeast BPS Pumps



WEMCO PUMP SDM 400/600HP







Southeast BPS Pumps

WEIR SPECIALTY PUMPS

SUCTION	PIPING (in)	
ITEM	Nom. Diam Equiv Lenç	132
elbow LR	0 0	132
elbow SR	0 0	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	24 24	132
pipe 2	0 0	132
gage corr.	· 22	

DATE:*	5/26/2006
PUMP TYPE:*	UNI GLIDE
MODEL NUMBER:*	UNI GLIDE 24X16
SERIAL NUMBER:*	05DU00013-02
PUMP TAG NO:	N/A
IMPELLER TRIM:	FULL
JOB NUMBER:*	DU00013
BUYER:	JCLINDUSTRIES
P. O. NUMBER:	F06316/510007
TEST BY:*	MATT

DISCH	IARGE PIPING (in)	
ITEM	Nom. Diam Equiv Leng	C
elbow LR	16 26	132
elbow SR	16 26	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	16 16	132
pipe 2	0 0	132
gage corr.	• 22	

Cond. Pt.	GPM	TH	RPM	Eff
1	8330	130	1190	89
2				
3				
4				

PUMP PERFORMANCE @ 68°F

320.2

335.5

86.3%

85.3%

133.4

110.2

INSTRUMENT	DATA
FLOW#:	3933
D-PSI#:	3955
S-PSI#:	3926
KW #:	2684
RPM#: 3	2688

			CUSTOMER	MOTOR		
		HP SIZE:	350	VOLTS	3 460	
ITEM	0/4 LOAD	1/4 LOAD	2/4 LOAD	3/4 LOAD	4/4 LOAD	5/4 LOAE
efficiency:	0.001					
corr.%eff:	0.001			_		egistera a delibbera de de en gracia
	watt sca	ale factor:=	1	1	v-belt%eff.	1

8207.0

10280.0

COMMENTS: 24" flow meter

POINT NUMBER	water temp. `F	discharge pressure PSI	suction pressure PSI	Average AMPS	PUMP SPEED (RPM)	FLOW RATE (GPM)	TOTAL HEAD (FEET)	CLEAR WATER HORSE- POWER	PUMP EFF. (%)
1	71.4	88.3	7.3	-75.4	1191.8	1.1	187.0	242.1	0.0%
2	71.2	74.6	7.4	-75.4	1191.8	4204.8	156.6	269.4	61.7%
3	71.4	71.4	7.3	-75.4	1189.9	6255.1	151.1	295.3	80.8%
4	71.5	62.4	7.2	-75.4	1189.5	8332.0	132.7	320.7	87.0%
5	71.4	53.1	6.9	-75.4	1188.8	10283.6	114.2	333.6	88.9%
Cathcart 00)1 Correcte	d results a	at 1190 rpm	ı					
1			•			161.0	183.9	227.8	3.3%
						2069.0	1 6 6.2	227.2	38.2%
1						4099.0	160.3	260.6	63.7%
1						6158.0	150.3	293.3	79.7%

Southeast BPS Pumps

WEIR SPECIALTY PUMPS

SUCTION	PIPING (in)	
ITEM	Nom. Diam Equiv Lenç	132
elbow LR	0 0	132
elbow SR	0 0	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	24 24	132
pipe 2	0 0	132
gage corr.	• 22	

DATE:*	5/25/2006
PUMP TYPE:*	UNI GLIDE
MODEL NUMBER:*	UNI GLIDE 24X16
SERIAL NUMBER:*	05DU00013-01
PUMP TAG NO:	N/A
IMPELLER TRIM:	FULL
JOB NUMBER:*	DU00013
BUYER:	JOHNDUSTRIES
P. O. NUMBER:	F06316/510007
TEST BY:*	MATT

DISCH	IARGE PIPING (in)	
ITEM	Nom. Diam Equiv Leng	C
elbow LR	16 26	132
elbow SR	16 26	132
sud.exp.1	0 0	132
sud.exp.2	0 0	132
pipe 1*	16 16	132
pipe 2	0 0	132

100	1.1	CUS	TOME	RFL	OW R	EQUI	REME	VTS	. 3.
Con	d. Pt.	(GPM	+ 34.50	TH	1911	RPM	450	Eff
	1		8330		130		1190		89
	2								
	3								
	4								

INSTRUME	NT DATA
FLOW#:	3933
D-PSI#:	3955
S-PSI#:	3926
KW #:	2684
RPM#:	2688

	CUSTOMER MOTOR					
		HP SIZE:	350	VO	LTS 460	
ITEM	0/4 LOAD	1/4 LOAD	2/4 LOAD	3/4 LC)AD 4/4 LC	OAD 5/4 LOAD
efficiency:	0.001					
corr.%eff:	0.001					
	watt sc	ale factor:=	1		v-belt%	eff. 1

COMMENTS: 24" flow meter

DUMBE	PERFORI	A A NICE	

	make a factor of		and the same of the same of	a fitti ya ta					
								CLEAR	
POINT NUMBER	water temp. 'F	discharge pressure PSI	suction pressure PSI	Average Amps	PUMP SPEED (RPM)	FLOW RATE (GPM)	TOTAL HEAD (FEET)	WATER HORSE- POWER	PUMP EFF. (%)
4 .	68.0	87.0	9.0	285.0	1189.9	0.0	180.1	235.5	0.0%
2	67.8	76.8	9.0	316.0	1188.5	4203.6	158.0	268.1	62.6%
3	67.5	73.4	8.9	342.0	1187.2	6255.9	152.0	293.7	81.8%
4	67.9	64.5	8.8	385.0	1186.4	8330.1	133.6	320.8	87.6%
5	67.5	55.0	8.5	368.0	1185.7	10283.6	115.0	337.0	88.6%
Cathcart 00	01 Correcte	d results	at 1190 rpm			167.0	181.3	231.4	3.3%
			•			2070.0	168.1	230.5	38.1%
						4067.0	159.2	262.7	62.2%
l						5959.0	151.5	293.2	77.8%
						8217.0	132.6	318.9	86.3%
						10280.0	112.1	330.7	88.0%
i									



System: Wichita, KS				Data Logge	r Installation Form
City Telog Serial No.: 7(153	Main Size:	1211	Fire Hydrant	Nozzle Diamete	r: 4.5"
	Pressure (psi)	-	Date	-	Time
Installe	ed: 93		04/04/14		12:07pm
Remove	d:		04/04/14		2:37 pm
Location: Pawner	and Meridia	en ac	ross the stre	et from Q	wiktrip (Ne
Sketch:					
		TN			
	QT X	Sunflow	ver nome h	leath E, ho	spice sign
-	3	Z Z	P	rawnee	
		Wendian			4.
a.]¥)`				0
2	}				
Photos:					
	£				,
					°.
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System: Wichita, KS		D	ata Logger Installation Form
City Telog Serial No.: 16157	Main Size: 36 11	Fire Hydrant Nozzle	Diameter: 2.5"
<u>P</u>	Pressure (psi)	Date	Time
Installed:	87	04/04/14	12:34pm
Removed:			
	+(N) between av	apaho and brum	inet
Sketch:			
	Church (pond 1 N	
anne	Prime Lois	julia	
,			
Photos:			



System: Wichita, KS	Data Logger Installation Form
City Telog Serial No.: 76157 Main Size: 81 off of	Fire Hydrant Nozzle Diameter: 2.511
Pressure (psi)	Date Time
Installed: 87	04/04/16 12:42 pm
Removed:	04/06/10 2:58pm
Location: on the corner of Arapas	ho and Maple St (SN)
Sketch:	
church	1 N
303 304 min	Maplest.
and and	
Photos:	
a 	
<u> </u>	





System: Wichita, KS		Data Logger Installation Form			
City Telog Serial No.: 76154	Main Size:	offof12 Fire Hydran	t Nozzle Diameter:	2.511	
	Pressure (psi)	Date	_	Time	
Installed	86	04/04/201	<u>U</u>	12159pm	
Removed:		04/04/2014	,	3:05pm	
Location: SE Corne	er of Doris St	and Central			
Sketch:					
1	1	NZ			
		cent	tal		
Jan Wede	18 735				
of the order		dans		,	
Photos:					
				1	





System: Wichita, KS	Data Logger Installation Form
City Telog Serial No.: 10 Main Size: 12" off 6.	Fire Hydrant Nozzle Diameter: 2.511
Pressure (psi)	Date Time
Installed: 8)	04/04/14 1:15pm
Removed:	04/06/16 3: 14pm
The state of the s	North Share
Sketch:	
LU300) X Tech S 21st S Sel Suldani M Con par	dit union N7
Photos:	
и	-
x.	
•	





System: Wichita, KS	A	Data	Logger Installation Form
City Telog Serial No.: 70159 Mair	Size: 911 offet 2011	Fire Hydrant Nozzle Di	ameter: 2.511
Pressure (p	osi)	Date	Time
Installed:		04/04/14	1:38 pm
Removed:		04/06/14	3:31pm
Location: NE corner of 38	thst and ar	kansas	
Sketch:			
	(1022)	14	
	3825 X		
38th S	+ 5 (621)		
	8	180	
Photos:			
ė.			3
<u> </u>			





System: Wichita, KS	Data Logge	r Installation Form
City Telog Serial No.: Main Size: 2011	Fire Hydrant Nozzle Diameter	2.5"
Pressure (psi)	Date	Time
Installed: 56	04/04/14	2:16pm
Removed:	H/06/20110	3:52pm
Location: On the NE corner of north	olkand woods/aun	
Sketch:		
2nd st	ockwood N	
Ailary ara familia	Norfalk Dr	
Photos:		
*	e	
n n		
<u> </u>		





System: Wichita, KS	- · · · · · · · · · · · · · · · · · · ·	Data I	ogger Installation Form
City Telog Serial No.: 76152	Main Size: 2411	Fire Hydrant Nozzle Dia	meter: 2.511
	Pressure (psi)	Date	Time
Installed	57	04/04/16	2:45pm
Removed		04/06/2010	4:06pm
Location: On 2/s	t St and tallgras	cs in front of bro	nokdall senjor
ketch:			
	8600 Brookd Server L Solut	o N inny inny	7
Stelltwo	1 215+ 5	5t swar	
hotos:			





System: Wichita, KS			Da	ata Logger Installation Form
City Telog Serial No.: 140161	Main Size:	20"	Fire Hydrant Nozzle	Diameter: 2.5"
Pr	essure (psi)	_	Date	Time
Installed:		6	4/04/16	3:17pm
Removed:		l	14/06/14	4:29pm
Location: On the Sou	therest con	nerof	15-94 and	'central
Sketch:				
			MA	TN
		kanza busine	ss park	
	X	(entral	
	1597	cutter petcar cente	re Neu 7	15
Photos:				
t.				
E.	å			
	*			





System: wichita, KS		Data Log	ger Installation Form
City Telog Serial No.: 10150	Main Size: 161	Fire Hydrant Nozzle Diamet	er: 2.5"
Pressur	e (psi)	Date	Time
Installed:		04/04/16	3:48pm
Removed:		04/06/10	4:49 p
Location: ON N CUYNE	r of hillside a	nd pawnel infront	of QT.
Sketch:		1	
15		Ln	*
	1 1	pawnee	
diadha	hilling		
Photos:			
•	<i>\\</i>		







Date:	04	1051	10
	VV	0 -	W

8:05 an Time:

Main Size:

811

FH Nozzle Size:

2.5"

Static Pressure

(psi)

Flowing Pressure (psi)

Flow (gpm)

99 Hydrant A:

97

NA

Hydrant C:

99

55

1250

Location:

on maxwell between mendian and custer

Sketch:

Centernatustines (c) 2097 (c) 2091	pawner Batlanta La)(1) Iwik. marvel	merdan
	squanhah	





Date: 04/05/2016

Time: 8:35

Main Size:

911

FH Nozzle Size:

2-5"

Static Pressure

Pressure (psi) Flowing Pressure (psi)

Flow (gpm)

Hydrant A:

94

99

NA

Hydrant C:

910

45-55

1130-1250

Location: On west 35 th St. S. between Hower Rd and Dugan Ave.

Sketch:

brunnet grant gran





System: Wichita, Kansas

Hydrant Test Form

Date: 04 05	le	Time: 9:03
Main Size:	FH Noz	zle Size: 2.811
Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A: 90	86	NA
Hydrant C: 92	65-67	1350-1375
Location: On MIKEST be	tween N. Newell.	sti west 3idst N.

Sketch:	central	NT
	x(a) sop	
	445 × (c) St Louis.	
	3rd	







Time: 9:27am

Main Size:

FH Nozzle Size:

2.51

Static Pressure (psi) Flowing Pressure (psi)

Flow (gpm)

Hydrant A: 82

79

NA

Hydrant C: 85

52.5

Wasses IN

Location: On S. Turquoise Between Evergnen In and Topaz St.

Sketch:

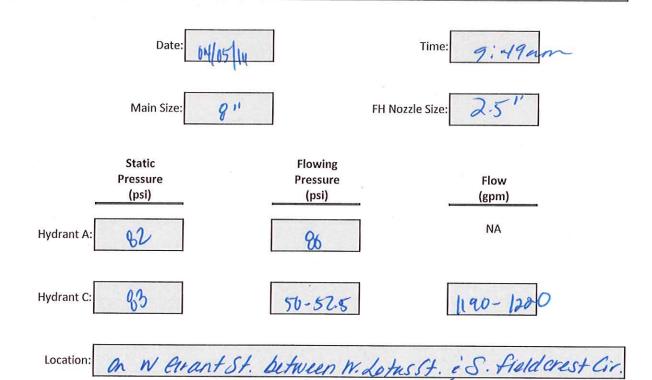
Maple

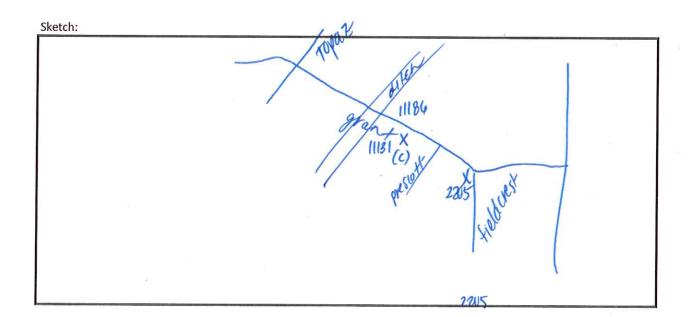
Socol of loyd

The state of the state of









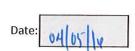




System: Wichita, Kansas **Hydrant Test Form** Date: 04/05/10 Time: 107 13a 0,1 2511 Main Size: FH Nozzle Size: Static **Flowing** Pressure Pressure Flow (psi) (psi) (gpm) NA Hydrant A: NH Hydrant C: 1130-1220 Location: DN. Parknoge St between W. taylor St i Binker Lane Sketch: (a) 1536 noie 45 X 454 Benter







Time: 10: 30 ar

Main Size:

FH Nozzle Size: 2.5"

Static Pressure (psi)

Flowing Pressure (psi)

Flow (gpm)

Hydrant A:

77

13

NA

POST FEST 14-18 Hydrant C: 7

40.58

1060-1250

Location:

N. She ford between W. MAMSIN. & W. 15th St N.

Sketch:

15th (x) (a) - 12 the middle of two hours.





1155

Hydrant A:

Date:

Main Size:

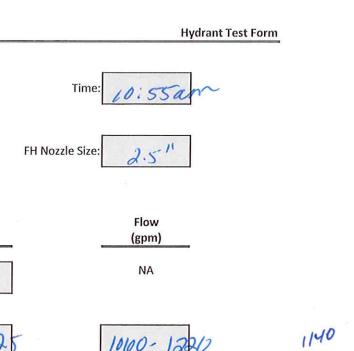
Static

Pressure

(psi)

04/05/14

811



Location: On N. Parkdale St. between Gentral Park Sti Sterling St.

Flowing

Pressure

(psi)

60

Sketch:

String

Audumnum

(a) x and all

2400 kg a 2422





(i)

Date: 04/5/2019

Time: 11:14an

Main Size:

811

FH Nozzle Size:

2.51

Static Pressure (psi)

Flowing Pressure (psi)

Flow (gpm)

Hydrant A: 74

68

NA

Hydrant C:

50

1190

N3734

Location:

on: on Pepper Ridge between Shadow lake Sti Forest Parkst.

Sketch:

Forest park

NT

(X) 3222

Pepperridge Ct 3202 - 3222

Minimal

Pepperridge Ct 3144 - 3166

Shadow lake







Date: 04/05/14

Time: 12:49/m

Main Size:

FH Nozzle Size: 2.511

Static Pressure (psi) Flowing Pressure (psi)

Flow (gpm)

Hydrant A:

28

NA

Hydrant C: 78

45-50

1130-1190

1140

Location: on Barrington St. between Westlawn St ; teatime.

Ballingtingtinstia)

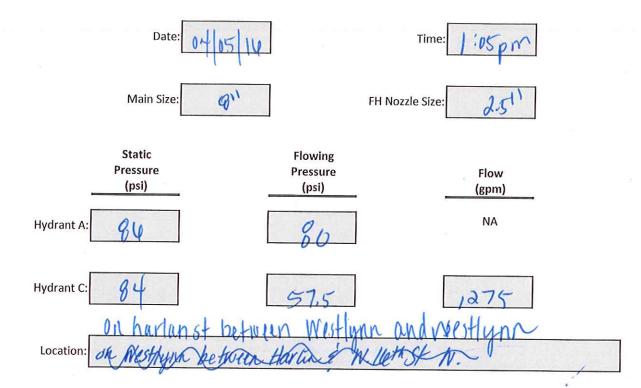
W Westlawn

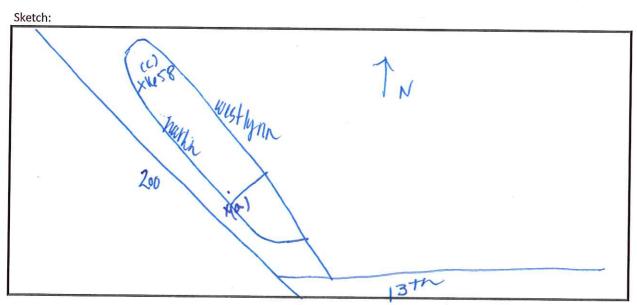
Substantia



Sketch:

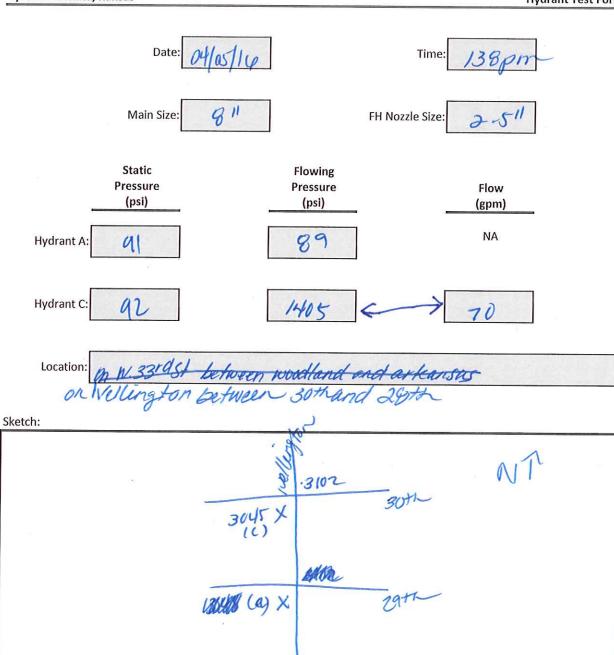
















Date: 04/05/10

2:01 pr Time:

Main Size:

2.5 FH Nozzle Size:

Static Pressure

(psi)

Flowing Pressure (psi)

Flow (gpm)

Hydrant A:

NA

Hydrant C:

86

45.50

1130-1190

luo

on 47thst between junette é salina are. Location:

Sketch:

arkansas X4757







	Date: 04/05///	4	Time: 2:31 pn
	Main Size:	FH Nozzl	tle Size: 2.5"
. Pr	Static ressure (psi)	Flowing Pressure (psi)	Flow (gpm) NA
Hydrant C:	77	45. 47.5	1130-11600 114
	N. iranward St. 6	between ironwoodc.	t e'. N. spyglusseir.
etch:		X(9) H322	NT
	1100 WOO	dct. Ironwood	





Date: 04/05/10

811

Time: 2:54pm

Main Size:

F

FH Nozzle Size: 2.5"

Static

Pressure (psi) Flowing Pressure (psi)

Flow (gpm)

Hydrant A: 75

44

NA

Hydrant C:

71

40-45

1060-1130

Location: on penstemon between E. 32 Mg N & E29 mst N.

Sketch:

TN

32ndsf

Nic Phyris Inc.

old villas of waterford perinstemmen

movie theater

2qthst







Time: 3:21 pm

Main Size:

811

FH Nozzle Size:

Static Pressure

(psi)

Flowing

Pressure (psi)

Flow (gpm)

Hydrant A:

NA

78 Hydrant C:

50-525

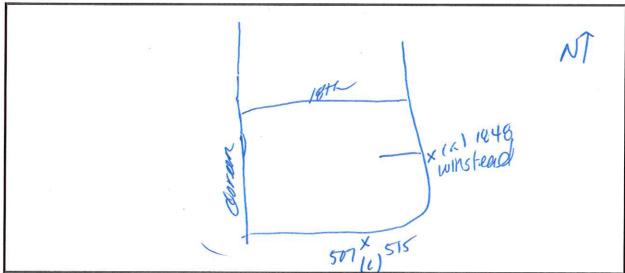
1190-1220

1205

Location:

Wastead/E. MASTN. between E. 18thst Nº N. Coreenst.

Sketch:





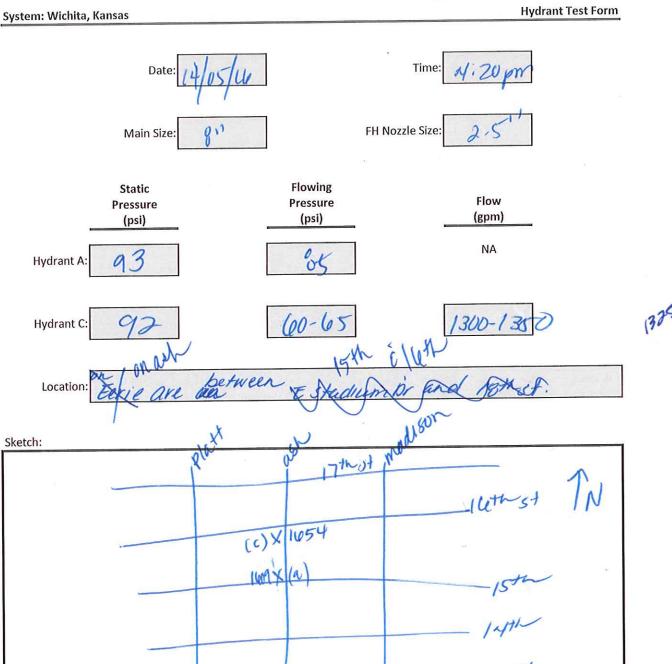


Main Size: FH Nozzle Size: Static **Flowing** Pressure Pressure Flow (psi) (psi) (gpm) NA Hydrant A: 1000-1130 70 Hydrant C Location: on N. Battin St between afterdale St i E. 27th St. Sketch: glendale pattin

pembrook











	Date:	4/05/14		Time:	4:41 pm	
	Main Size:	9"		FH Nozzle Size:	25"	
	Static Pressure (psi)	_	Flowing Pressure (psi)		Flow (gpm)	
Hydrant A:	54		50		NA	
Hydrant C:	57		32.5		960	
Location:	on williams.	bury be	tweenh	archy ar	d E 13th	v.
ketch:	on williams.	0		1;ansper	Y	
ketcii.			V	ntu.	13†	7-St
			1.0			NT
			(a)			
		Ilthyt	X/(c)/112	8		
			1			





5:06pm Time: 911 Main Size: FH Nozzle Size: Static **Flowing** Pressure Pressure Flow (psi) (psi) (gpm) NA Hydrant A: 69 12.5 Hydrant C: 1220 Location: on Broadmoor from Rutland to Central

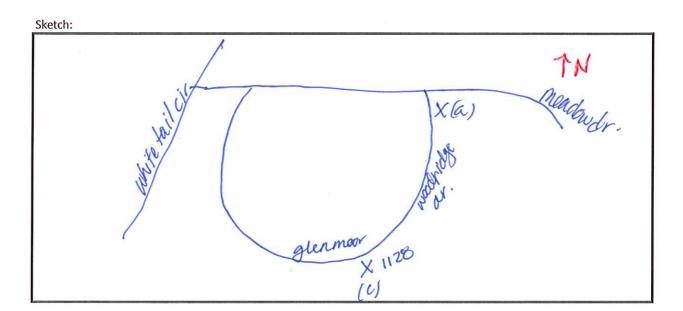
elm (n) X
Sus





Hydrant Test Form System: Wichita, Kansas 9:33a Date: 04/64/14 Time: gn 2.51 Main Size: FH Nozzle Size: Static **Flowing** Pressure Pressure Flow (psi) (psi) (gpm) NA Hydrant A: 1015 1000-1030 Hydrant C: 102

Location: on woodingge dr. off of meadow drive



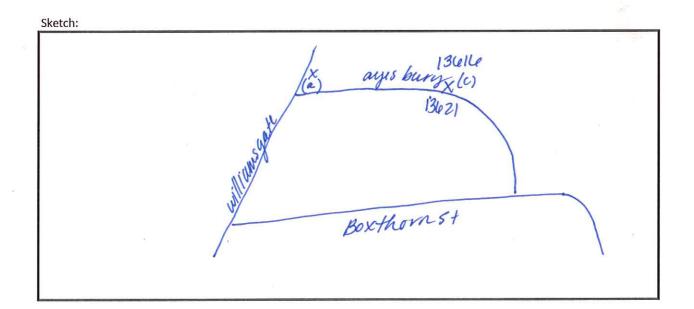






System: Wichita, Kansas

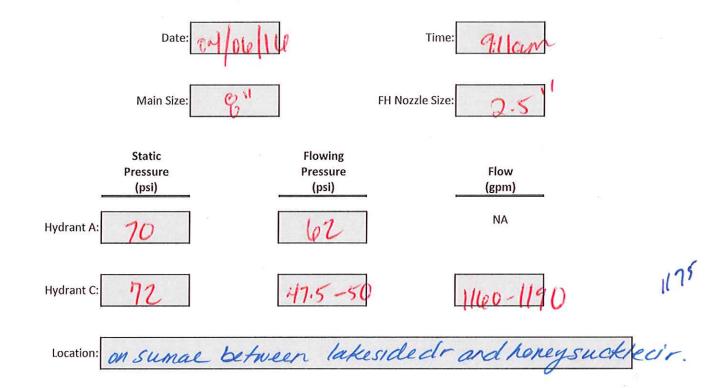
Date: 0 4/04/14		Time: 8:54am
Main Size:		FH Nozzle Size: 2.5
Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A:	42	NA
Hydrant C: 62	45	1/30
Location: on questionist	hetween	williams agre and box Hemst

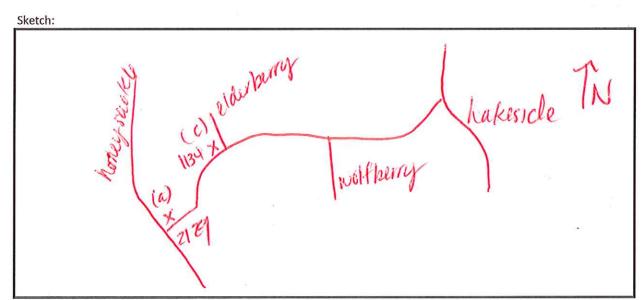


















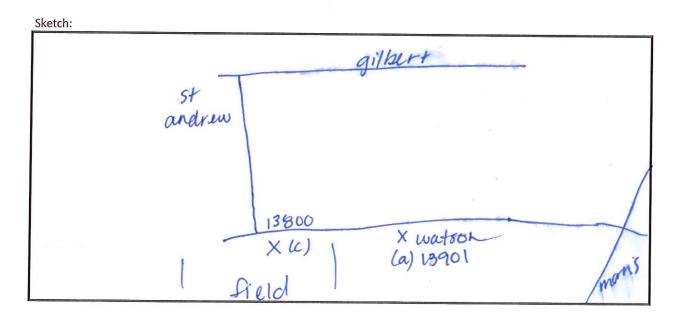
Date: ON OL	16	Time: 9:43 am	
Main Size:	FH Noz	czle Size: 2.5	
Static Pressure (psi) Hydrant A:	Flowing Pressure (psi)	Flow (gpm) NA	
Hydrant C:	50-52-5	1190-1220	1206
Location: on south lakes	ide dr between	green ralley	dr é elmst
:	gratialler		
elm		int.	TN
	Static Pressure (psi) Hydrant A: Wigh BY Location: On South lakes h:	Static Pressure (psi) Hydrant A: Pressure (psi) Hydrant C: By TB Location: On South lakevide dr between h: deg wood waterly 118 walk	Static Pressure (psi) Pressure (psi) (gpm) Hydrant A: My BY NA Hydrant C: By Co-524 1190-1220 Location: On South lakeside dr between green ralley h: walnut NA Hydrant C: By My







Date: Office	14	Time: 10:02am	
Main Size:	FH Nozz	le Size: 2.5	
Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)	
Hydrant A: 80 - 84	74	NA	
Hydrant C: 80 - 82	4-53	1130-1250	1190
Location: Onst Andrews S.	f /watson between	morns stig	Therty











Date: ON/OLE	12016	Time: 10: 210 av
Main Size:	A	FH Nozzle Size: 2.511
Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A: 43	62	NA
Hydrant C:	3 - 4 - 4 - 4 - 4 - 4 - 4 - 4 - 4 - 4 -	1060-1130
Location: On Indenst &	etween cherry	roreckdr and caprisst







Date: 14/01/14	Time: 10:48am
Main Size:	FH Nozzle Size: 2.51
Pressure Pro	owing essure (psi) NA
	1325
Location: on distante de betu	oun grand and zimmerly
etch:	
Sapare	Reyal 1119 1 201 Marry 5 +







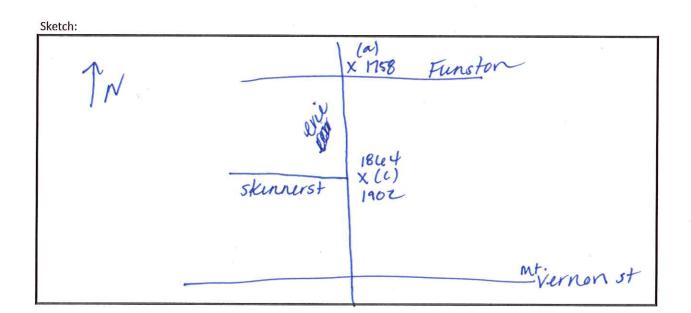
Date: 14/66/14	Time: 11:20an
Main Size:	FH Nozzle Size: 2.51
Static Flowin Pressure (psi) (psi)	re Flow (gpm)
Hydrant C: 81	*
Location: The Nas Sav between wa	Kellsk f. XIX tenare. I sterman st and English St
on vassav between wa	To man CST what ing the VC.
×(a) 350	english TN
Masser 1	
(c) X	waturman







Date: 04/00/1	Q	Time: 12:31 pm
Main Size:		FH Nozzle Size: 2.51
Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm)
Hydrant A: 90	93	NA
Hydrant C: 90	70-75	1405-1455
Location: on porio of ha	Luces Karn	an o Lun-ton









	Date: Off Obj	14	Time: 12:55pm	
	Main Size:		FH Nozzle Size: 2-511	
	Static Pressure	Flowing Pressure	Flow	
	(psi)	(psi)	(gpm)	
_	(1.5.7		(BP····)	
Hydrant A:	VA A	97	NA	
Trydrant A.	[00	87		
Hydrant C:	102	40-75	1300-1455	ľ
	her beid	5+1	Canous Santa +	2
Location:	A Kinkaid	between paie	sen and textended	
Sketch:			*	
		2159		
NT		(c)X	21551	
	Kinkaid	525 \$000	-	
		3		
		81	\ \mathref{\pi}.	
		W /	100	







Date:	04/14	Time: 1:21 pm	
Main Size:	8M	FH Nozzle Size: 2.5	
Static Pressure (psi) Hydrant A:	Flowing Pressure (psi)	Flow (gpm) NA	
Hydrant C: 108 Location: On management	10-80 gar between mo	pattyst victoria natane and E. SSTEST.	1400
setch:	· ·		
	Pattyst (C) (C) (C) (C) (C) (C)	mona la serio 5438 may wood 5546+	nl







Date: 311 Main Size: FH Nozzle Size: Static **Flowing** Pressure Pressure Flow (psi) (psi) (gpm) NA 99 Hydrant A: Hydrant C: on wysidsts between Mendian & Waysthst. Location:

Sketch:

47(c) X 2713

47(c) X 2713

Mendian

Sketch:





System: Wichita, Kansas

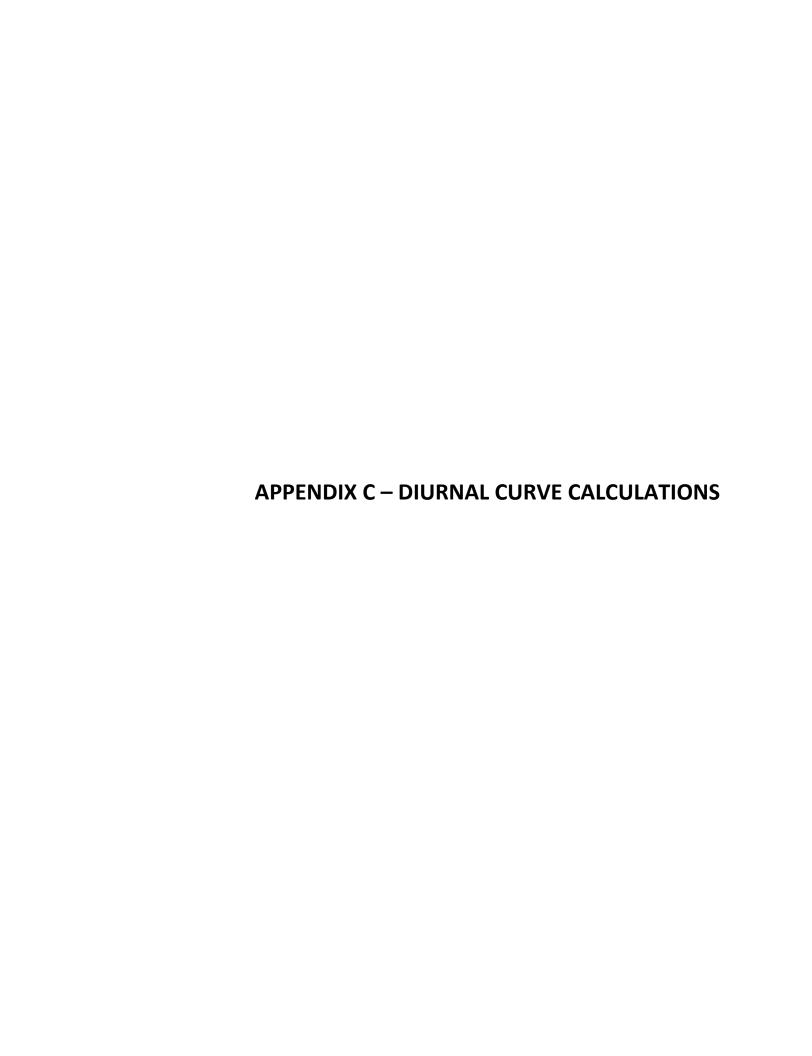
0-160 psi with 2016 intervalson face

	Date: 64 06 1	le	Time: 2:13 pm	
	Main Size: 8 11		FH Nozzle Size: 2.51	
Hydrant A:	Static Pressure (psi)	Flowing Pressure (psi)	Flow (gpm) NA	
Hydrant C:	100	50-60	1190-1300	12-45
Location:	on Martinson bo	tween 1	the Cormick and Walker	
etch:	3			
NT			mdornuck	
		(a) × 1102	ining	

121X (c) 1202



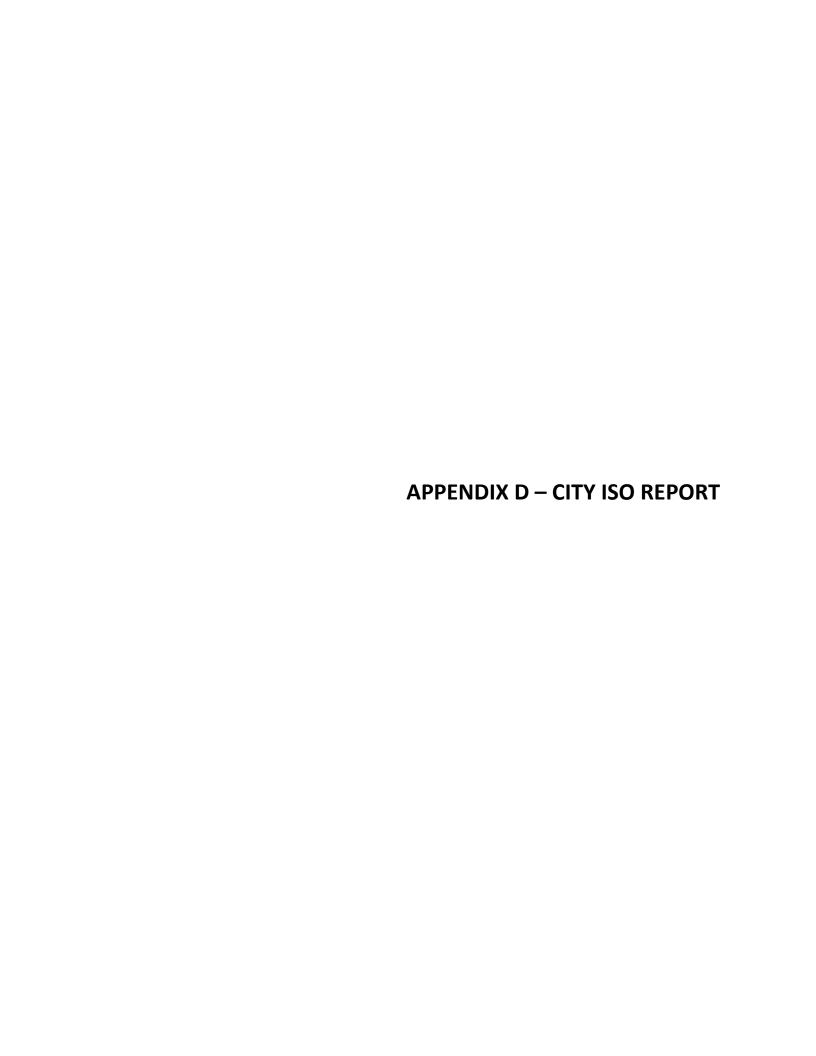




	luraba.	h Bood Classocall (10						-	East Press	ure Zone	NE	Pressure Zone		6-	itire System	-		East Pressure Zone	Nort	heart Pressure Zone	-	West M	Innia Praceura Zona			ace Practure Zone	
		MG)		,	. , ,				E BPS	Webb Road BPS	Webb Road BPS	37th		emand Equalization S	torage Equalization		d Equalization	on Storage Equalization	Tot Demand Equalizatio	Storage Equalization	Diurnal Tot Deman	nd Equalization S		Diurnal			Diurnal
	Date Time ((feet) (MG)	(feet) (MG) (feet)	(MG) (MG)	(MG) (g	(MG)	(MG)	(MG)	(MG) (MG)	(MG) (MG) (MG)	(MG) (F	IGD) (MG)							(%) (MGD)	(MG)		(%)			(%)
	1	10.59 (0.21)	27.2	(0.01) 25.9	0.00 34.2	36.0 1	44 0.03	0.09	0.0	0.1 3.2	1.5 1.5	0.0	0.0	36 16				4	8 2 2					100	31 11		100 74
	3	11.64 (0.26)	25.7	0.06 25.7	0.00 29.4	28.6 1	14 0.26	0.00	0.0	2.2 1.9	1.9 1.8	0.0		34 18 28 23			4.7	2	3 1 2 8 2 1						32 10 25 17		77 59
					0.01 29.1 (0.14) 46.1	29.4	52 0.00	0.00	0.7	5.7 3.7				29 22 29 23				3 6	4 2 1 7 2 1					- 11	25 17 22 20		60 53
						46.1 21 55.2 1	84 0.36 75 0.41	1.56	0.0 1.6	8.0 5.7 11.6 8.0				46 6 56	(4)		0.8			(0)					37 5 41	2	88 96
	8 9	10.64 0.28	29.1	(0.09) 29.2	(0.06) 63.0	69.7 1	40 0.25	0.77	0.0	10.2 11.6 9.3 10.2	1.8 2.5	3.0	3.3	70	(18)	135 11.6		-5.1 17		(3)	189 0.	0.25		145	52 47	(10)	125
			29.6	0.04 30.7		56.0 9	95 0.13	0.84	0.1	7.8 9.3	2.4 2.4	1.0	1.1	56	(4)	109 9.5		-3.0 14		(0)	113 0.	0.13 0.05	(0.03)	74	43	(1)	103
	12	9.44 0.10	29.1	(0.01) 30.6	(0.01) 58.0	58.4 8	31 0.03	0.60	0.8	7.2 7.8				58	(7)	113 7.2		-0.7	0 3	(0)	107 0.	0.03 0.14		19		(6)	110
	13 14	9.34 0.05 9.1 0.10	29.3	(0.01) 30.1	0.02 58.9 - 57.9	58.0 10 58.9 11	65 0.12 29 0.24	0.41	0.6	7.5 7.0 6.2 7.5	1.9 2.0	0.9	0.9	58 59	(6)	112 7.6 114 7.9		-1.4 12	1 3 0		96 0.	0.24	(0.06)	137	47 48	(5) (6)	113 114
		9.0 0.05				57.9	0 0.19	0.06	0.1	5.7 6.2				58 55	(6)								(0.01)	107		(7)	116 111
		8.7 0.10	28.8	0.05 30.0	0.05 56.3	54.8 10	00 0.13	2.17	1.5	6.8 6.5	1.9 1.9	0.9	1.0	55 56	(3)			-1.5	3 3 0		94 0.			76 92		(2)	105
	19	8.5 0.05	27.4	0.04 27.8	0.08 60.3	58.2 2	26 0.18	1.05	1.1	5.8 5.9	0.0 2.1	3.2	1.0	58	(7)	113 7.1		-0.6	9 3	(0)	100 0.	0.18			48	(6)	114
State Stat	21	9.0 (0.15)	26.4	(0.02) 24.6	0.05 63.9	61.3 2	08 0.23	0.00	1.3	6.2 6.7	0.0 0.0	2.7	4.1	61	(10)	118 8.1		-1.6 12	4 4	(1)	133 0.	0.23	(0.05)	130	49	(7)	120
		9.2 (0.10) 9.2 -	27.0 26.3	(0.03) 24.1 0.04 24.1	- 41.5	49.6 1	74 0.30 24 0.11	0.00	0.0	4.4 6.2 3.5 4.4		0.9	0.9	64 50 2	(12)								(0.13)		55 43 (0)	(13)	130 101
	24	9.4 (0.11)	25.4	0.05 24.1	0.00 39.6	41.5 5	58 0.18	0.00	0.6	3.3 3.5	1.4 1.7	0.8	0.9	41 10		80 4.1	2.4	6	3 3 0		84 0.	0.18	(0.01)	103	35 7		83
						51.7	0.17		0.5	6.0	1.8		1.3	52 120	(120) 10	100 6.5	27.4	-27.4 18 10	0 3 9	(9) 12.33	100 0.	0.17 1	(1) 26	6 100	42 87	(87) 8.58	100
							58	0.00		3.34	1.4					80		6	3		84			103	-		83
	2:00	10.3 (0.26)	26.7	0.01 24.1	0.00 32.9	36.4	0.08	0.00	0.0	2.68 3	0.0 0.0	1.3	1.3	36.1 14		72 3.4	2.5				51 0.	0.08		55	34 8 31 10		75
	4:00	10.9 (0.05)	25.7	0.07 24.8	(0.04) 26.8	27.7 2	29 0.09	0.17	0.0	2.75 3	0.0 0.0	1.4	1.3	32.6 18 27.7 22		55 2.7	3.2	4	5 1 1 5 1 1		52 0.	0.09		61	29 13 24 18		69 57
						26.8 5 30.5 1	51 0.04 68 0.07	0.81	0.2	4.86 3 7.75 5								4	9 1 1 6 3	(1)				28 48	22 19 22 20		54 52
	7:00		25.7	(0.04) 26.1	(0.03) 65.0	57.9 2	21 0.24	1.86	1.4	8.54 8	1.8 2.7	3.0	1.1	57.9	(8)	115 9.1		-3.2 15	4 4	(1)	145 0.	0.24		157	45 50	(3)	108
State	9:00	10.6 0.05	27.5	(0.05) 29.3	(0.12) 57.7	65.2 5	55 0.20	0.00	1.5	5.71 7	2.1 2.6	1.0	1.1	65.1	(15)	130 8.5		-2.6 14	4 4	(1)	141 0.	0.20	(0.05)	132	53	(11)	127
Second	11:00	10.5 0.05	30.5	(0.02) 30.8	(0.02) 53.0	54.8 7	73 0.16	1.20	0.8	6.11 5	1.9 1.9	0.9	0.9	54.8	(5)	109 5.6	0.3	9	5 3	(0)	108 0.	0.16	(0.00)	101	46	(5)	111
	13:00	10.5	30.2	0.02 30.1	0.01 52.2	52.4 1	0.11 19 0.07	0.62	1.2	5.26 6 4.63 5	2.2 1.7	1.0	0.9	52.5	(2)	105 6.3		-0.4 10	7 3	(0)	101 0.	0.07 0.08		47	44	(2)	103
10 10 10 10 10 10 10 10	15:00	10.5 -	30.5	(0.01) 30.3	0.00 52.2	52.5 9	33 0.15	0.56	0.4	4.12 4	1.6 1.7	0.9	0.9	52.5	(2)	105 4.8	1.1			(1)	99 0.	0.15		18 97	45	(2)	105 108
1		10.6 -	30.0 29.7	0.03 29.4	0.05 51.7 0.03 52.4	52.2 1 51.7 1	49 0.13 15 0.21	0.00	0.6	5.46 4 4.52 5	1.8 1.6 1.5 1.8	0.9	0.9		(2)					(0)	96 0. 102 0.	0.13 0.02	(0.06)			(3)	108 105
State Stat	18:00	10.7 -	29.4	0.02 28.5	0.03 52.7	52.4 1:	53 0.17	0.96	0.8	5.16 5	1.8 1.5	0.9	0.8		(2)	104 5.3				(0)	91 0.	0.17	(0.01)	108		(3)	107
Column C	20:00	10.8	29.1	0.03 28.7	0.00 60.0	60.4 8	34 0.08	2.17	2.3	8.13 7	1.9 1.6	0.9	0.9	60.4	(10)	120 9.3		-3.4 15	8 2 0	(0)	93 0.	0.08	,		49	(7)	117
State Stat	22:00		27.7	(0.00) 28.6	0.00 57.0	64.1 2	63 0.45	0.00	0.0	5.17 8	1.6 1.8	0.8	0.9	64.0	(14)	128 7.8		-1.9	2 3	(0)	102 0.	0.45			53	(12)	113 128
Section Sect				(0.04) 28.5 (0.03) 28.5	0.00 50.4 0.00 36.8	57.0 1- 50.4 3	42 0.38 19 0.20	0.00							(7)			8	8 2 0 8 2 1					133	49 44	(8)	118 106
1						50.2			0.7	5.2	1.6		1.0	50 108	(108) 9	100 5.9	22.0	-22.0 16 10	0 2.6 7	(7) 11	100 0.	0.15 1	(1) 28	8 100	41.6 88	(88) 9	9 100
1	A (C /2016 BAide inha	11.0	20.0	20.5	200	3	10	0.00		2.25	1.6	1 00			,	100		-			20		1.0	122		1000	106
Column C	1:00		29.2	(0.01) 28.4	0.00 32.0	36.8 1:		0.30		1.68 3	1.6 1.6	0.0		37 15				5	3 2 1						32 11		74
The column	3:00	13.7 (0.31)	29.6	(0.00) 28.2	0.00 32.2		4 0.20 18 0.01	0.24	0.3	1.94 2 2.39 2	2.2 1.9	0.0	0.0	32 20 34 18		65 2.2	4.1	3	1 2 1 5 2 1		65 0.	0.01 0.17	(0.02)	113	28 14 30 13		66 70
1		14.3 (0.26) 14.3 -			0.00 36.3 (0.02) 40.1	36.3 1:	26 0.04	1.22	0.6	6.26 3	2.5 2.2 1.0 2.5	0.0 3.7	0.0	32 20 36 15				4	2 2 1 4 3 0					15 22	27 15 30 13		64 70
1							46 0.29	0.64	1.6	11.12 8				40 12 57	(5)					(2)						1	66 98
	8:00	13.4 0.26	28.6	(0.08) 28.6	(0.06) 64.8	63.2	0 0.35	1.29	0.6	7.79 11	2.8 1.8	1.1	3.0	63	(11)	122 11.8		-5.4 18	6 5	(2)	162 0.				47	(4)	110
Column C	10:00	13.0 0.08	30.3	(0.06) 31.4	(0.10) 58.8	61.1	63 0.20	0.00	1.1	5.26 7	2.2 2.8	1.0	1.1	61	(9)	118 7.9		-1.6	5 4	(1)	131 0.					(7)	116
The column The	12:00	12.8 0.05	31.9	(0.05) 33.3	(0.05) 52.8	57.5 4	49 0.32	0.39	1.4	4.61 6	2.0 2.1	1.0	1.0	57	(6)	111 7.7				(0)	105 0.	0.32				(4)	110
The column		12.5 0.05	30.1	0.04 33.3	0.00 51.4	53.8 1	16 0.23	0.00	0.8	5.60 5	2.7 1.5	0.0	0.8	53 54	(1)	104 5.9	0.4	7	9 3 3 2 1	(0)			(0.06)	40 132	45 46	(2)	106 107
State		12.3 0.10 12.2 0.06	30.8 30.5	(0.04) 33.3 0.02 33.2	- 53.7 0.00 53.2	51.4 6 53.7 1:	36 0.17 34 0.10	0.90 2.34	0.0	5.04 6 7.29 5				51 0 54	(2)			8 9	9 3 0					96 55		(1)	101 107
Mary		12.0 0.10	29.8			53.2 3	36 0.19	0.00	2.3	6.42 7				53	(2)				2 3 0				(0.02)	111	41	1 (2)	97 105
The column	19:00	11.8 0.05	27.7	0.04 29.0	0.04 61.1	54.5 1:	21 0.22	0.00	0.5	6.56 7	2.1 2.1	1.0	0.9	55	(3)	105 7.4		-1.1 11		(0)	103 0.	0.22			44	(2)	104
The column The	21:00			0.02 28.1	0.04 66.0	61.0 1	55 0.21	0.71	1.2	7.06 7		0.9	0.9	61	(9)	118 8.4		-0.2 10 -2.0 13	2 3 0	(0)	100 0.	0.21	(0.04)	120	50	(7)	117
No.	23:00	11.2 0.11	30.8	(0.11) 31.6	(0.13) 46.8	62.5 5	14 0.22 51 0.16	0.00	0.0	4.06 6	2.3 2.1	0.0	1.0	62	(14)	120 5.7	0.6	-1.4 12 9	1 3	(0)	104 0.	0.16 0.01	(0.05)		55	(11)	130 126
	0:00	11.1 0.05	30.9	(0.01) 32.3	(0.04) 32.4		97 0.07	0.00		3.79 4				47 5				6	4 2 1					42	40 2		95
No.						51.8			0.6	5.7	2.1		0.9	52 106	(106) 9	100 6.3	24.2	-24.2 16 10	0 3 8	(8) 11.36	100.00 0.	1.17	(1) 25	5 100	43 83	(83) 8.14	1 100.00
No.	4/7/2016 Midnight	11.1	30.9	32.3	32.4	32.4	0.14	0.00	0.0	3.8	2.0	0.0	0.0	32 19		100	2.9	6	8 1		70 68 0	114 0.01		42 108	26 15		95 64
Column C		10.8 0.08	29.2				28 0.00	0.00	0.0	4.3 4		0.0		30 21				5	4 2 1				(0.13)	-	24 17		58
No. Color			28.5	0.03 32.6			71 0.04	0.48	0.3			0.9		29 22				4	8 2 1								57
No. Color	6:00	11.0 0.05	28.5	(0.05) 31.0	0.05 47.4	32.7	95 0.10 95 0.09	1.69	0.5	7.9 7	1.3 2.5	3.9	1.0	32 19 33 18		64 7.0				(1)	120 0.	0.09		73	24 17		59
The control of the	8:00	10.8 0.05	26.3	0.03 27.9	0.05 65.8	66.7	93 0.27	1.89	2.3	8.5 10	1.6 1.3 1.1 1.6	3.4 2.9	3.9	48 3 67	(16)	131 12.2		-5.5 18	1 5	(2)	167 0.	0.27 0.14		207		(8)	79 120
10	9:00 10:00	10.5 0.05	28.6	(0.05) 30.1	(0.04) 59.7	65.8 1: 62.6 1-	56 0.28 46 0.22	0.54	1.9 0.5	7.7 9 7.2 8	2.5 1.1 2.0 2.5	1.1	2.9	66	(-0)	129 10.4 123 8.2		-1.5		(1) (1)	136 0.					(10) (9)	124 123
10	11:00	10.3 0.11	29.4	(0.04) 31.0	(0.05) 59.6	59.7 1	16 0.21	0.34	0.2	6.8 7	2.1 2.0	1.0	1.0	60	(9)	117 7.4		-0.7	0 3	(0)	100 0.	0.21 0.08	(0.11)	162	49	(8)	119 120
100 w w w w w w w	13:00	10.1 0.05	28.3	0.01 29.8	0.02 59.3 (0.09) 57.8	58.7 6	39 0.10	0.75	0.0	5.8 8	2.0 2.1	1.0	0.9	59 59	(8)	115 7.5		-0.8	1 3	(0)	102 0.	0.10	(0.03)		48	(7)	117 120
100 100	15:00	9.8 0.05	31.3	(0.09) 32.3	(0.05) 53.4	57.8 1	01 0.15	0.09	0.7	5.5 5	2.0 1.7	0.9	0.9	58	(7)	113 5.4	1.4	7	9 3 0		88 0.	0.15 0.02		117	50	(8)	121
150 150	17:00	9.5 0.11	29.8	0.08 31.1	0.07 54.0	53.5	0 0.05	2.25	2.2	6.5 7	1.8 1.7	0.9	0.9	54	(3)	105 8.9		-2.1 13	2 3 0		85 0.				42	(1)	109
1	19:00	9.3 0.05	28.1	0.02 29.1	0.03 56.5	54.4 1	18 0.19	0.94	1.0	5.4 6	1.8 2.0	0.9	1.0	55	(4)	107 6.8	0.0	-2.0 13 10	0 3	(0)	101 0.		(0:13)	150	45	(3)	104 108
228	21:00	8.9 0.10	26.5	0.05 27.6	0.05 62.5	57.1 1:	31 0.15	1.33	1.3	6.3 7	1.9 2.1	0.9	1.0	57	(6)	112 7.8				(0)	103 0.	0.15 0.02		118		(6)	115 112
	23:00	8.8 0.05	27.6	(0.12) 29.0	(0.03) 60.7 (0.05) 48.1	62.5 5 60.7 4	49 0.08	0.84	0.8	4.3 6 3.8 4	1.5 1.9 0.0 1.5	0.9 1.3	0.9	62 60	(11)	118 5.1	1.6				80 0.	0.08	(0.05)			(11) (12)	126 128
	0:00	9.7 (0.32)	31.5	(0.10) 28.9	0.00 44.8	48.1	0 0.07	0.00	0.3	3.8 4	0.0 0.0	1.3	1.3	48 3		93 4.1	2.6	6	1 1 2		44 0.	0.07	(0.06)	54	42 (1)		102
100 101 103						51.0			0.8	5.9	1.9		1.1	51 127	(127) 10	100 6.7	21.7	-21.7 13 10	0 3 7	(7) 10	100 0.	0.13 1	(1) 27	7 100	41 111	(111) 11.24	1 100
280 21		9.7	31.5	28.9			0			3.8	0.0		1.3			93		6	1		44			54			102
200 111 020 271 050 324 050 325 050 311 311 0 050 050 050 41 4 0 0 0 14 13 13 24 55 15 15 15 15 15 15 1	2:00	11 (0.21)	29	0.04 29	0.00 31.1	33.1 3	34 0.00	0.00	0.0	3.4 4 3.5 3	0.0 0.0		1.3	45 10 33 22		60 3.4	3.2	5	b 1 2 1 1 2		44 -	-	(0.17)	-			87 62
5.00	3:00 4:00	11.1 (0.21) 11.2 (0.05)	29.1 28.6	0.02 28.7	0.00 33.1	33.1 2	26 0.00	0.28	0.0	4.1 4 5.5 4	0.0 0.0 2.1 0.0		0.9 1.4	31 24 33 22		56 3.5 60 4.1	3.1 2.5				45 0. 46 -	-	(0.13) (0.17)	- 28	26 19 28 18		58 61
Property				0.07 26.1	0.05 64.0	48.9 2	83 0.04 29 0.26	1.26 0.00	0.3 1.3	8.2 5 0.0 8				33 22 49 6						(0) (1)			(0.14)	22 151			54 77
900 106 005 261 00.12 22 00.12 667 742 121 022 1.99 00 75 13 28 24 12 32 74 (19) 135 130 4.4 196 6 (10) 147 0.02 0.05 128 55 (10) 122 110 100 104 - 1 274 (10.08) 248 (10.01) 154 652 30 0.01 144 0.0 6.4 7 2.0 2.3 1.0 1.0 0.5 110 155 137 100 100 104 - 1 274 (10.08) 248 (10.05) 154 652 30 0.01 144 0.0 6.4 7 2.0 2.3 1.0 1.0 0.5 110 155 137 100 100 100 100 100 100 100 100 100 10	7:00	10.9 0.09	23.3	0.12 24.6	0.08 71.0 (0.03) 74.2	64.0 10 71.0 11	60 0.33	0.07	0.0		2.5 0.0	- 1	3.9	64 71	(9) (16)	117 0.0			4	(1)	132 0.	0.33 0.16		189	60	(15) (9)	133
1100 102 0 102 0 103 286 (0.01 9.4 6.2 30 0 119 1.14 0.0 6.4 7 2.0 2.3 1.0 1.0 65 (1.0 119 6.9 0.3 104 3 0 0 110 0.19 0.02 110 5.5 (1.0 119 1.14 0.0 119 0.19 0.02 110 1.0 5.5 (1.0 119 1.14 0.0 119 0.19 0.19 0.19 1.14 0.0 1.14 0.	9:00	10.6 0.05	26.1	(0.12) 27.2	(0.12) 66.7	74.2 1	21 0.22	1.59	0.0		2.8 2.4		1.2 3.2	74	(19)	135 13.0		-6.4 19	6 6	(3)	187 0.	0.22 0.05	(0.00)	128	55	(10)	122
1200 131 005 28 002 28	11:00	10.4	27.6	(0.03) 28.6	(0.01) 59.4	65.2	30 0.19	1.14	0.0	6.4 7	2.0 2.3		1.0	65	(10)	119 6.9		-0.3	4 3	(0)	110 0.	0.19 0.02		110	55	(10)	121
1500 48 0.05 24 0.04 23 0.03 544 559 135 0.25 127 0.6 6.2 5 20 2.3 0.8 1.0 56 11 10 0.25 0.07 141 47 1 13 74 6 12.0 14 14 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	13:00	10.1 0.06	28.8	(0.02) 29.6	(0.00) 57.4	57.0 6	59 0.17	0.11	0.1		2.4 2.3		1.0	59	(2)	104 6.7	0.0	10	0 3	(0)	112 0.	0.17	(0.01)	96	47	(4)	104
1600 96 0.10 274 0.06 224 0.05 611 544 139 0.19 2.66 1.3 7.4 6 2.0 2.0 1.0 0.9 55 0.9 1.13 3 0 1.13 3 0 1.15 0.05 0.1	15:00	9.8 0.05	29.1	0.04 29.3	0.03 54.4	55.9 1	35 0.25	1.27	0.6	5.3 6 6.2 5	2.3 2.4 2.0 2.3	-	0.9 1.0	56	(2) (1)	102 5.9	0.9			(0) (0)	110 0.	0.25 0.07	(0.08)		47	(3)	107 103
1800	16:00	9.6 0.10	27.4	0.06 28.4	0.05 61.1 (0.01) 61.0	54.4 1: 61.1 1:	39 0.19	2.46	1.3	7.4 6 6.9 7	2.0 2.0		1.0 0.9	55 0 61	(6)	99 7.5				(0)	98 0.	0.19 0.02		112		(3)	97 106
200 91 005 25 001 25 00	18:00	9.4 0.05	28.9	(0.07) 29.3	(0.04) 61.6	61.0 2	05 0.16	0.36	1.9		2.3 2.2		1.0	61	(6)	111 8.8		-2.1 13	2 3	(0)	106 0.	0.16	(0.02)	91		(4)	108
2200 95 01.61 275 020 95 021 31 003 28 00 517 579 44 026 00 11 45 5 20 17 09 09 58 (3) 105 63 03 95 3 0 88 026 09 180 49 6 19 19 19 19 19 19 19 19 19 19 19 19 19	20:00	9.0 0.05	29.5	(0.01) 29.6	0.01 62.5	60.8	41 0.29	0.00	1.1	5.9 5	2.1 2.1		1.0	61	(6)	111 6.5	0.1	9	8 3	(0)	103 0.	0.29 0.12		166	51	(6)	113
	22:00	9.5 (0.16)	29.5	(0.01) 29.4	0.00 53.7	57.9 4	14 0.26	0.00	1.1	5.2 6 4.5 5	2.0 1.7	- 1	0.9	58	(3)	105 6.3	0.3	9	5 3 0	(U)	88 0.	0.09	10.6	149	49	(8)	118
		9.9 (0.21) 10.5 (0.31)	30.1	(0.03) 29.4	0.00 52.1 0.01 47.6	53.7 3: 52.1 1/	19 0.06 84 0.46	0.47	0.0	3.4 5 4.3 3	1.6 2.0 1.6 1.6	(1.8 0.9	53 2				5	9 2 1		9/ 0. 83 0.		(0.11)		45 (1) 45 0		102 99
									0.6	6.1	1.8		1.2	55 111	(111) 8	100 6.6	27.0	-27.0 17 10	0 3 8	(8) 11	100 0.	1.17	(1) 27	7 100	45 91	(91) 8.39	100
										·																	

Appendix C WICHITA, KANSAS -- WATER DISTRIBUTION SYST

																		Entire System East Pressure Zone																											
	We	ebb Road Clean		Roosevelt To	ver (2 MG)	Woodlawn	Tower (2 MC	G) H	less Pump S	Station	West	Maple BPS	East Pressure Zone SE BPS Webb Road BPS					NE Pressu					Entire System										Northeast Pres					West Maple Pre					ressure Zone		
		MG))		(=)			-,						SE BPS				Webb R					Equalization			Diurnal			qualization Storage		on Diur			lization Storage		Diurnal	Tot Deman	d Equa	alization Storage				d Equalization Sto		
	1	Elevation	Volume	Elevation	Volume	Elevation	Volume	e Ra	ate	Volume	Rate	Volum	ie Rat	e V			/olume	Rate	Volume	Rate	Volume	Rate	Fill	Draft	Factor	Diame	Rate	F	Fill Draft	Factor	Dia	Rate	Fill	Draft	Factor	Diame	Rate		Draft	Factor	5101	Rate	Fill C	Draft Facto	,r
Date Ti	me	(feet)	(MG)	(feet)	(MG)	(feet)	(MG)	(M	AG)	(MG)	(gal)	(MG)	(MC	i)	(MG)	(MG)	(MG)	(MG)	(MG)	(MG)	(MG)	(MGD)	(MG)	(MG)	(%)	(%)	(MGD)	(1)	MG) (MG)	(%)	(%	6) (MGD) (MG	(MG)	(%)	(%)	(MGD)	(MG)) (MG	(%)	(%	i) (MGD)	(MG) (MG) (%)	(%)
4/9/2016 Mid	night	10.5		30.6		29.	3	47	7.6		184		0.00)		4.3		1.6		0.0	В						94					59					33					264			9'
1	:00	11.0	(0.26)	30.4	0.01	29.	2 0	000 39	9.2	47.6	342	0.27			0.0	3.6	4	2.4	1.6	0.1	0.8	47	7 2				95 4.3	1	1.9			69	2	1			79 0.	27	0.09			153 4	10 (0)		10
	:00	11.1	(0.05)	29.9	0.03	29.				39.2		0.49			0.1	3.7	4		2.4		0.0	36	10				79 3.7		2.5			60	2	1			31 0.		0.32			284 3	33 8		- 8
	:00	11.4	(0.15)	28.1	0.11	27			4.2			0.00			0.3	2.7	4		2.6		0.0	20	20				50 4.0		2.2		_	64	2	0			99 -	-		(0.17)			2 17	-	- 5
	:00	11.5	(0.25)	20.2	0.00	26	-			24.2	0				0.0	4.0	2		2.8		0.0	2	25				19 3.2		3.0	+	_	62	3	0		+	93 0.	oc.		(0.17)		22 1	10 22	-	- 5,
	:00	11.5	(0.03)	26.1	0.00	26.	-					0.00			0.0	6.7	3 4		2.0		1 0.0	21	10				52 4.0		2.2			65	3	0				00		(0.12)		32 3	24 17	-	- 43
	:00	12.0	(0.10)	26.5	0.07	26.		7.03		33.0		0.00			0.0	5.7	- 4		2.8		1 1.1	3.	19				56 5.7		0.5	+	_	03	4	0	(4)	1	70	00		(0.17)			17	-	33
	00	11.0	0.11)	25.0	0.04	26.	- 10			41.6		0.00			0.0	6.5	- 0		2.8		1.1	3:	1/				36 5.7		-0.3	_	_	106	4		(1)	-	29 0.	00	0.02	(0.17)	_	111 3	23 1/		
8			0.03		0.07											6.8						4,	8			-							4		(1)							100 3	31 9	-	
		11.8	0.05	26.6	(0.09)	27.	4 (0					0.19			0.5	7.3	7	2.8	2.6		1 1.0	4.	2 7				36 7.3		-1.0		_	117	4		(1)	1.	20 0.		0.02			109	31 9	$\overline{}$	78
	:00	11.5	0.10	27.2	(0.04)	28.	3 (0			59.8	132	0.16			0.0	7.2	7	2.4	2.8		1.1	60)	(10)		1	21 7.3		-1.1		_	117	4		(1)	1	32 0.			(0.02)		90 4	18	(8)	121
	:00	11.3	0.11	26.8	0.03	28.				59.8		0.19			1.6	7.0	7		2.4		1.0	60)	(10)		1	21 8.7		-2.5			141	3		(0)	1			0.02			109 4	18	(7)	118
11		11.2	0.05	26.9	(0.01)	28.				59.9		0.30			1.4	6.7	7		2.3		1.0	60)	(10)		1	21 8.4		-2.2			135	3		(0)	1			0.12			171 4	18	(8)	119
12		11.0	0.11	26.8	0.01	28.			9.4			0.21			1.3	6.0	7		2.2		1.0	60)	(11)		1	22 8.0		-1.8		_	129	3		(0)		0.		0.04			122 4	19	(9)	121
13		10.9	0.05	27.2	(0.02)	28.						0.38			1.1	6.5	6		2.1		1.0	59	9	(10)		1	20 7.0		-0.8		_	113	3		(0)	10			0.21			218 4	19	(9)	127
	:00	10.7	0.11	28.0	(0.05)	29.	4 (0	0.05) 59		59.4	106			,	1.4	6.2	7		2.2	1.0	1.0	55	9	(10)		1	20 7.9		-1.7			127	3		(0)	10	0.	22	0.05			129 4	18	(8)	120
15	:00	10.6	0.05	28.5	(0.03)	29.	8 (0	0.02) 57	7.0	59.0	110	0.15	1.09	;	1.4	5.6	6	2.1	2.1	1.0	1.0	59	9	(9)		1	19 7.6		-1.4			122	3		(0)	10	0.5	15		(0.02)		88 4	18	(8)	120
16	:00	10.4	0.11	27.6	0.05	28.	7 0	0.06 52	2.6	57.0	85	0.16	0.0)	1.0	6.0	6	1.9	2.1	0.5	9 1.0	57	7	(8)		1	15 6.6		-0.4			107	3		(0)	1	0.	16		(0.02)		91 4	17	(7)	11/
17	:00	10.3	0.05	26.2	0.08	27.	1 0	0.09 58	8.5	52.6	161	0.12	0.0)	0.0	7.1	6	1.8	1.9	0.5	0.9	53	3	(3)		1	07 6.0	0	0.3			96	3	0			94 0.	12		(0.05)		71 4	14	(4)	101
18	:00	10.2	0.05	25.3	0.05	26.	3 0	0.05 59	9.8	58.5	130	0.23	2.4)	0.0	7.1	7	1.7	1.8	0.5	0.9	59	9	(9)		1	18 7.1		-0.9			115	3	0			39 0.	23	0.06			133 4	19	(8)	121
19	:00	10.1	0.05	27.2	(0.11)	27.	3 (0	0.06) 56	6.9	59.8	183	0.19	0.8	ı	2.4	4.8	7	1.8	1.7	0.5	0.9	60)	(10)		1	20 9.5		-3.3			153	3	0			36 0.	19	0.01			108 4	17	(7)	11/
20	:00	10.3	(0.10)	28.4	(0.07)	27.	3 0	0.00 58	8.1	56.9	91	0.26	0.9	,	0.8	4.8	5	1.8	1.8	0.5	0.9	57	7	(7)		1	14 5.6		0.6			90	3	0			92 0.	26	0.09			152 4	18	(8)	12'
21	-00	10.7	(0.21)	29.0	(0.04)	27.	3 0	000 54	4.0	58.1	52	0.13			1.0	5.0	5	1.7	1.8	0.0	0.9	S	1	(8)		1	17 5.7		0.5			93	3	0			39 0.	13		(0.04)		75 4	19	(9)	12
22		10.7	- (0.22)	30.2	(0.07)	27.	3 (0		3.0			0.07			1.0	4.4	5		1.7		0.8	S	1	(4)		1	09 6.0		0.2			97	3	0			36 0.			(0.10)		43 4	15	(5)	11'
	:00	10.8	(0.05)	28.7	0.09	27.				43.0	66				0.0	3.7	4	2.2	2.5		0.0	4:	7	(-)			37 4.4		1.8			70	3	0			35 0.			(0.08)		55 3	86 4	- (0)	9
0.		11.1	(0.16)	29.7	(0.06)	26				44.1		0.10			0.7	2.0	4	2.1	2.2		0.0	4/					39 4.4		1.8		_	71	2	1			74 0			(0.08)		55 2	27 2	-	- 0
		****	(0.10)	25.7	(0.00)	20.	, ,		4.3	44.2		0.10	0.0	_	0.7	2.0				0.1	0.0						2.7		1.0		_	-/-	-	-			0.	10		(0.00)			,,,	-	
										49.6					0.7				2.3		0.7	50	121	(121)	10		0 62	1"	17.6 -17.6		12	100	2		(6)	7 1	0	17	1	(1)	25	100	105	(105)	10.90 100
										43.0					0.7		5.5		2.3		0.7		,	(222)	10		. U.L		-17.0		**	100	3		(2)			17		(-/)		100	103	(103)	0.50
4/10/2016 Mid	night	11.1		29.7		26.	9	34	4.5		70		0.0)		2.8		2.1		0.0	o o						39					71					74					55			9'
1:	:00	11.8	(0.31)	28.7	0.06	25.	7 0	0.07 34	4.6	34.5	24	0.10	0.4	,	0.0	1.9	3	2.2	2.1	0.1	0.0	34	1 18				56 2.8	3	3.2			47	2	1			70 0.	10		(0.07)		60 2	29 14		6'
2	00	12.2	(0.21)	28.6	0.00	25.	7 0	000 30	0.3	34.6	0	0.04	0.4		0.5	2.0	2	2.2	2.2	0.1	0.0	34	1 18				56 2.4		3.6			40	2	1			71 0.	04		(0.13)		21 3	80 13		7
3:		12.6	(0.21)	29.6	(0.06)	25	_			30.3	3				0.4	2.1	2		2.2		0.0	3/	22				58 2.4		3.7			39	2	1			74 -	-		(0.17)		- 3	25 17	-	9
4		13.0	(0.21)	29.5	0.01	25	6 0			30.1	54				0.5	3.0	2		2.5		0.0	20	22				58 2.5		3.5			42	2	1			82 0	00		(0.16)		2 2	19		
	:00	13.3	(0.16)	27.5	0.01	25	6 0			30.6		0.08			0.4	5.0	2		2.6		0.0	2:	22				59 3.4		2.6		_	56	2	0						(0.09)		46 2	24 18		- 5
6		13.3	0.10)	27.1	0.11	27.				35.3		0.08			0.4	5.0	5		3.1		0.0	3.	17				58 5.2		0.8	_	_	97	2	0	(0)	1	,,			(0.03)		22 2	27 16	-	- 51
	:00	13.2	0.03	27.1	0.02	26.				35.3	141				0.0	5.0	5		2.5		1.0	3.	17				58 5.0		1.0	_	_	92	3		(0)		18 0.		0.04	(0.11)	_	121 2	7 16	-	- 03
8		13.0	0.10	25.8	0.06	26.				35.3	147				0.0	4.8	5		2.6		1.0	33	1/				59 4.8		1.0		_	83	4	_	(1)		20 0.		0.04	_	_	121 2	27 16	-+-	62
		12.8		24.8	0.06											6.0	5					30	10							_	_	80	4		(1)						_	120 2	27 16		- 0:
	:00		0.05	26.8	(0.12)	27.				59.3		0.21			1.0	7.0	ь		2.7		1.1	55	,	(7)		1	13 7.0		-1.0		_	116	4		(1)		24 0.		0.04			126 4	18	(5)	112
	:00	12.5	0.10	27.9	(0.06)	29.			3.8			0.18			1.7	6.5	7		2.5		1.0	64	1	(12)		1	23 8.7		-2.7		_	144	3		(0)		16 0.		0.02			110 5	51	(9)	120
11		12.4	0.05	29.0	(0.06)	30.			4.1			0.11			1.2	7.3	6		2.1		1.0	64	1	(12)		1	7.6		-1.6			126	3	_	(U)		0.			(0.06)		63 5	53	(10)	123
	:00	12.2	0.10	30.0	(0.06)	31.				64.1	124				0.7	7.2	7		2.2		1.0	64	1	(12)		1	23 8.0		-2.0			133	3		(0)		0.		0.07			141 5	53	(10)	123
13	.00	12.1	0.05	30.1	(0.01)	31.	, 10			64.3	143				0.0	6.9	7		2.1		1.0	64	1	(12)		1	23 7.2		-1.2		_	120	3		(0)	10	,,		0.01			106 5	54	(11)	125
	:00	11.9	0.10	29.6	0.03	30.	- 0			63.6		0.21			1.4	6.5	7		2.3		1.0	64	1	(12)		1	22 8.4		-2.3		_	139	3		(0)	1			0.04			123 5	52	(9)	12*
15		11.8	0.05	30.0	(0.02)	30.				63.7		0.25			1.2	6.1	7		2.3		1.0	64	1	(12)		1	22 7.7		-1.7			128	3		(0)	10			0.08			147 5	52	(10)	12
	:00	11.5	0.10	30.0	(0.00)	31.						0.23			0.0	7.0	6		2.2		1.0	63	3	(11)		1	21 6.1		-0.1			102	3		(0)		0.		0.06			135 5	54	(11)	12
17		11.4	0.05	29.3	0.04	30.				63.5	171				0.0	6.7	7		2.2		1.0	64	1	(12)		1	22 7.0		-1.0			116	3		(0)	1				(0.01)		95 5	53	(11)	125
18	:00	11.2	0.10	29.1	0.01	30.	3 (0	0.00) 67	7.2	65.6	213	0.25	0.0)	0.0	8.9	7	2.5	2.2	1.	1.0	66	5	(14)		1	26 6.7		-0.7			112	3		(0)	1	0.	25	0.08			147 5	56	(13)	13'
19	:00	11.0	0.11	28.9	0.01	30.	1 0	0.02 66	6.9	67.2	220	0.31			0.0	8.4	9		2.5	1.0	1.1	67	7	(15)		1	29 8.9		-2.9			147	4		(1)	1	18 0.	31	0.14			183 5	55	(12)	127
20	1:00	10.9	0.05	29.1	(0.01)	29.	6 0	0.03 66	6.1	66.9	76	0.32	1.3	,	0.0	6.4	8	2.2	2.2	1.0	1.0	67	7	(15)		1	29 8.4		-2.3			139	3		(0)	10	0.0	32	0.15			189 5	55	(12)	129
21	:00	10.9	-	28.6	0.02	28.	7 0	0.05 61	1.5	66.1	84	0.11	1.4	ò	1.4	6.5	6	2.2	2.2	1.0	1.0	66	5	(14)		1	27 7.8		-1.7			129	3		(0)	10	0.	11		(0.06)		66 5	55	(12)	129
22	:00	10.8	0.05	28.9	(0.02)	28.	7 0			61.5	339	0.12			1.5	4.7	6		2.2		1.0	62	2	(10)		1	18 7.9		-1.9			132	3		(0)	11	0.	12		(0.05)		73 5	50	(7)	117
23		10.8		29.4	(0,02)	28.				50.1		0.49			1.0	2.6	5		2.6		0.0	- C) 2	/			96 5.7		0.3			95	3	0					0.32			291 4	11 2		9
0		11.0	(0.10)	28.1	0.02	27.			1.2			1	0.2		0.3	2.6	3		2.0		0.0	33	15					3				48	2	1			is -			(0.17)			11		7
	-		(0.20)		0.07		t		-				0.2			-		1			0.0	<u> </u>																							
								-		52.1					0.6		5.5		2.3		0.7	61	168	(168)	13	1	00 6.0	2	23.1 -23.1	1 .	16	100	3	5	(5) 6,6	9 1	00 0.	17	1	(1)	27	100 4	13 141	(141)	13.68 100



Public Protection Classification Summary Report

Wichita

Kansas

Prepared by

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May 16, 2012

Background Information

Introduction

ISO collects and evaluates information from communities in the United States on their structure fire suppression capabilities. The data is analyzed using our Fire Suppression Rating Schedule (FSRS™) and then a Public Protection Classification (PPC™) number is assigned to the community. The surveys are conducted whenever it appears that there is a possibility of a classification change. As such, the PPC program provides important, up-to-date information about fire protection services throughout the country.

The Fire Suppression Rating Schedule (FSRS) recognizes fire protection features only as they relate to suppression of first alarm structure fires. In many communities, fire suppression may be only a small part of the fire department's overall responsibility. ISO recognizes the dynamic and comprehensive duties of a community's fire service, and understands the complex decisions a community must make in planning and delivering emergency services. However, in developing a community's Public Protection Classification, only features related to reducing property losses from structural fires are evaluated. Multiple alarms, simultaneous incidents and life safety are not considered in this evaluation. The PPC program evaluates the fire protection for small to average size buildings. Specific properties with a Needed Fire Flow in excess of 3,500 gpm are evaluated separately and assigned an individual classification.

A community's investment in fire mitigation is a proven and reliable predictor of future fire losses. Statistical data on insurance losses bears out the relationship between excellent fire protection – as measured by the PPC program – and low fire losses. So, insurance companies use PPC information for marketing, underwriting, and to help establish fair premiums for homeowners and commercial fire insurance. In general, the price of fire insurance in a community with a good PPC is substantially lower than in a community with a poor PPC, assuming all other factors are equal.

ISO is an independent company that serves insurance companies, communities, fire departments, insurance regulators, and others by providing information about risk. ISO's expert staff collects information about municipal fire suppression efforts in communities throughout the United States. In each of those communities, ISO analyzes the relevant data and assigns a Public Protection Classification – a number from 1 to 10. Class 1 represents an exemplary fire suppression program, and Class 10 indicates that the area's fire suppression program does not meet ISO's minimum criteria.

ISO's PPC program evaluates communities according to a uniform set of criteria, incorporating nationally recognized standards developed by the National Fire Protection Association and the American Water Works Association. A community's PPC depends on:

- ➤ **Needed Fire Flows**, which are representative building locations used to determine the theoretical amount of water necessary for fire suppression purposes.
- Receiving and Handling Fire Alarms, including telephone systems, telephone lines, staffing, and dispatching systems.
- Fire Department, including equipment, staffing, training, and geographic distribution of fire companies.
- ➤ Water Supply, including condition and maintenance of hydrants, alternative water supply operations, and a careful evaluation of the amount of available water compared with the amount needed to suppress fires up to 3,500 gpm.

Data Collection and Analysis

ISO has evaluated and classified over 48,000 fire protection areas across the United States using its Fire Suppression Rating Schedule (FSRS). A combination of meetings between trained ISO field representatives and the dispatch center coordinator, community fire official, and water superintendent is used in conjunction with a comprehensive questionnaire to collect the data necessary to determine the PPC number. In order for a community to obtain a classification better then a Class 9, three elements of fire suppression features are reviewed. These three elements are Receiving and Handling Fire Alarms, Fire Department and Water Supply.

A review of the **Receiving and Handling Fire Alarms** fire alarm and communication system accounts for 10% of the total classification. The review focuses on the community's facilities and support for handling and dispatching fire alarms. This section is weighted at **10 points**, as follows:

Telephone Service 2 points
 Number of Needed Operators 3 points
 Dispatch Circuits 5 points

A review of the **Fire Department** accounts for 50% of the total classification. ISO focuses on a fire department's first alarm response and initial attack to minimize potential loss. In this section, ISO reviews such items as engine companies, ladder or service companies, distribution of fire stations and fire companies, equipment carried on apparatus, pumping capacity, reserve apparatus, department personnel, and training. The fire department section is weighted at **50 points**, as follows:

•	Engine Companies	10 points
•	Reserve Pumpers	1 point
•	Pumper Capacity	5 points
•	Ladder/Service Companies	5 points
•	Reserve Ladder/Service Trucks	1 point
•	Distribution of Companies	4 points
•	Company Personnel	15 points
•	Training	9 points

A review of the **Water Supply** system accounts for 40% of the total classification. ISO reviews the water supply a community uses to determine the adequacy for fire suppression purposes. Hydrant size, type, and installation is also considered, as well as the inspection frequency and condition of fire hydrants. The water supply system is weighted at **40 points**, as follows:

•	Credit for Supply System	35 points
•	Hydrant Size, Type & Installation	2 points
•	Inspection/Condition of Hydrants	3 points

There is one additional factor considered in calculating the final score – **Divergence**.

Even the best fire department will be less than fully effective if it has an inadequate water supply. Similarly, even a superior water supply will be less than fully effective if the fire department lacks the equipment or personnel to use the water. The FSRS score is subject to modification by a divergence factor, which recognizes disparity between the effectiveness of the fire department and the water supply.

The Divergence factor mathematically reduces the score based upon the relative difference between the fire department and water supply scores. The factor is introduced in the final equation.

Public Protection Classification Number

The PPC number assigned to the community will depend on the community's score on a 100-point scale:

PPC	Points
1	90.00 or more
2	80.00 to 89.99
3	70.00 to 79.99
4	60.00 to 69.99
5	50.00 to 59.99
6	40.00 to 49.99
7	30.00 to 39.99
8	20.00 to 29.99
9	10.00 to 19.99
10	0.00 to 9.99

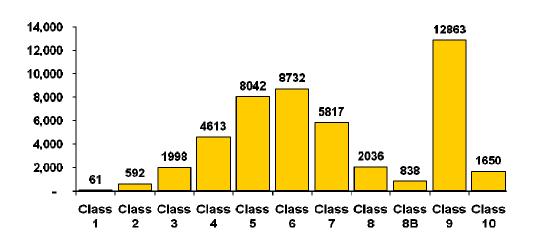
The classification numbers are interpreted as follows:

- Class 1 through (and including) Class 8 represents a fire suppression system that includes an FSRS creditable dispatch center, fire department, and water supply.
- Class 8B is a special classification that recognizes a superior level of fire
 protection in otherwise Class 9 areas. It is designed to represent a fire protection
 delivery system that is superior except for a lack of a water supply system
 capable of the minimum FSRS fire flow criteria of 250 gpm for 2 hours.
- Class 9 is a fire suppression system that includes a creditable dispatch center, fire department but no FSRS creditable water supply.
- Class 10 does not meet minimum FSRS criteria for recognition.

Distribution of Public Protection Classification Numbers

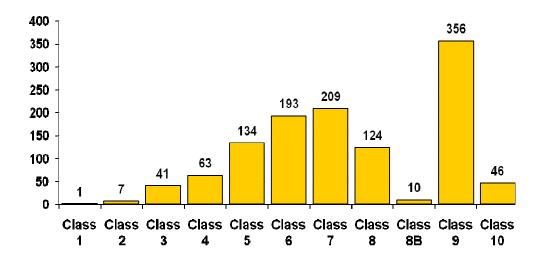
The 2011 published countrywide distribution of communities by the Public Protection Classification number is as follows:

Countrywide



The 2011 published statewide distribution of communities by the Public Protection Classification number is as follows:

Kansas



Assistance

The PPC program offers help to communities, fire departments and other public officials as they plan for, budget, and justify improvements. ISO is also available to assist in the understanding of the details of this evaluation.

ISO Public Protection representatives can be reached by telephone at (800) 444-4554. The technical specialists at this telephone number have access to the details of this evaluation and can effectively speak with you about your PPC questions. What's more, we can be reached via the internet at www.isomitigation.com/talk/.

We also have a website dedicated to our Community Hazard Mitigation Classification programs at www.isomitigation.com. Here, fire chiefs, building code officials, community leaders and other interested citizens can access a wealth of data describing the criteria used in evaluating how cities and towns are protecting residents from fire and other natural hazards. This website will allow you to learn more about ISO's Public Protection Classification program. The website provides important background information, insights about the PPC grading processes and technical documents. ISO is also pleased to offer Fire Chiefs Online — a special secured website with information and features that can help improve your ISO Public Protection Classification, including a list of the Needed Fire Flows for all the commercial occupancies ISO has on file for your community. Visitors to the site can download information, see statistical results and also contact ISO for assistance.

In addition, on-line access to the Fire Suppression Rating Schedule and its commentaries is available to registered customers for a fee. However, fire chiefs and community chief administrative officials are given access privileges to this information without charge.

To become a registered fire chief or community chief administrative official, register at www.isomitigation.com.

Classification Details

Public Protection Classification

ISO concluded its review of the fire suppression features being provided for/by Wichita. The resulting community classification is **Class 3**.

If the classification is a single class, the classification applies to properties with a Needed Fire Flow of 3,500 gpm or less in the community. If the classification is a split class (e.g., 6/9), the following applies:

- ➤ The first class (e.g., "6" in a 6/9) applies to properties within 5 road miles of a recognized fire station and within 1,000 feet of a fire hydrant or alternate water supply.
- Class 8B or class 9 applies to properties beyond 1,000 feet of a fire hydrant but within 5 road miles of a recognized fire station.
- Alternative Water Supply: The first class (e.g., "6" in a 6/10) applies to properties within 5 road miles of a recognized fire station with no hydrant distance requirement.
- Class 10 applies to properties over 5 road miles of a recognized fire station.
- Specific properties with a Needed Fire Flow in excess of 3,500 gpm are evaluated separately and assigned an individual classification.

Summary Evaluation Analysis

The following points represent the analysis of the application of the criteria outlined in the FSRS of four topics– Receiving and Handling Fire Alarms, Fire Department, Water Supply, and the Divergence factor for Wichita:

FSRS Feature	Earned Credit	Credit Available
Receiving and Handling Fire Alarms 414. Credit for Telephone Service	1.90	2
422. Credit for Operators 432. Credit for Dispatch Circuits	3.00 5.00	3 5
440. Credit for Receiving and Handling Fire Alarms	9.90	10
Fire Department		
513. Credit for Engine Companies	7.01	10
523. Credit for Reserve Pumpers	0.66	1
532. Credit for Pumper Capacity	5.00	5
549. Credit for Ladder Service	3.32	5
553. Credit for Reserve Ladder and Service Trucks 561. Credit for Distribution	0.46 1.93	1 4
571. Credit for Company Personnel	8.93	15
580. Credit for Training	7.68	9
590. Credit for Fire Department	34.99	50
Water Supply		
616. Credit for Supply System	34.23	35
621. Credit for Hydrants	1.98	2
631. Credit for Inspection and Condition	2.40	3
640. Credit for Water Supply	38.61	40
Divergence	-5.31	
Total Credit	78.19	100

General Information

To determine the Total Credit, the points for Receiving and Handling Fire Alarms, Fire Department and Water Supply are added together and the Divergence factor is applied. To establish the points for each category, FSRS items labeled as "Credit for..." are totaled. These particular items are intermediate values. Usually these intermediate values are based upon a 100-point scale, but they can be different. The ratios between the actual points scored in each of these sub-items and the points available for full credit are then multiplied by the points available for the sub-item.

For instance, Item 414 "Credit for Telephone Service (CTS)" is valued at 2 points. To determine the credit earned, the totals for Item 411 "Review of Telephone Lines (TL)", Item 412 "Review of Telephone Directory (TD)", and Item 413 "Review of Recording Device (RD)" are summed. In Item 411, up to 60 points can accrue; Item 412 has a combined value of 20 points; and 20 points are available for Item 413. The sum of these three Items is divided by 100 and then multiplied by the 2 point weight in Item 414 to determine the final score for "Credit for Telephone Service (CTS)".

The formula for Item 414 "Credit for Telephone Service (CTS)" looks like this:

$$\mathbf{CTS} = \frac{\mathbf{TS}}{\mathbf{100}} \times 2$$

Where TS = TL + TD + RD

Detailed Evaluation Analysis

On the following pages are the details of the evaluation of each category for Wichita. These details relate only to the fire insurance classification for this jurisdiction. They are not for property loss prevention or life safety purposes and no life safety or property loss recommendations are made.

At the end of the detailed analysis the relative class is indicated. The relative class represents the classification each category would have achieved if the individual score was translated into a 100-point scale instead of the points available for that category.

Receiving and Handling Fire Alarms

Ten percent of a community's overall score is based on how well the communications center receives and dispatches fire alarms. Our field representative evaluated:

- the telephone service, including the number of telephone lines coming into the center
- the listing of the emergency number and business number in the telephone directory
- the automatic recording of emergency calls
- the communications center, including the number of operators on-duty and awake at the center
- the dispatch circuits and how the center notifies firefighters about the location of the emergency

Item 414 - Credit for Telephone Service (2 points)

The first item reviewed is Item 414 "Credit for Telephone Service (CTS)". This item reviews the facilities provided for the public to report fires including the telephone line used to report an emergency, business and private alarm lines including progression of emergency calls to business lines. Also analyzed is the listing of fire and business numbers in the telephone directory and the automatic recording of emergency calls. ISO uses National Fire Protection Association (NFPA) 1221, Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems as the reference for this section.

To determine the score for Item 414, three sub-items (Item 411, Item 412, and Item 413) were evaluated. The details are as follows:

Item 411 - "Review of Telephone Lines (TL)"	Earned Credit	Credit Available
A. Number of needed fire lines*	25.00	25
For maximum credit, there should be 8 incoming telephone lines reserved for receiving notification of fires. The Communication Center serving Wichita has 20 lines reserved.		
The telephone directory listed both a business and an emergency number.		
B. Number of needed fire, business, and private alarm lines*	25.00	25
For maximum credit, there should be 8 incoming lines reserved for notification of fires (and other emergency calls) plus 3 additional lines for conducting other fire department business and, if applicable, for private alarms.		
The Communication Center serving Wichita has 3 lines in addition to the 20 lines reserved for receiving notification of fires (and other emergency calls).		
The telephone directory listed both a business and an emergency number.		
C. Progression of emergency calls to business lines	10.00	10
For maximum credit, unanswered emergency calls should progress to the business number.		
D. If detailed information of a fire is received and transmitted through more than one communication center, DEDUCT	0.00	-20
For no deduction of points, fire calls should be immediately transferred from the answering point to the dispatcher who will then obtain the needed information from the caller for dispatching.		
Review of Telephone Lines (TL) total:	60.00	60

*Note: When only one telephone number is listed in the telephone directory the telephone lines provided cannot be reserved for emergency calls because the general public is not given a choice of telephone lines to use. Therefore, the operator/telecommunicator must accept both emergency and business calls over the same lines. The number of needed fire, business, and alarm lines will show a reduction in credit.

Item 412 - "Review of Telephone Directory (TD)"	Earned Credit	Credit Available
A. Emergency number on the inside front cover or the front page	10	10
For credit, the fire emergency telephone number should be printed on the inside front cover or front page of the white pages in the telephone directory.		
B. Emergency number and business number listed under "Fire Department"	0	5
For credit, both the number to report a fire and the fire department business number should be listed under "FIRE DEPARTMENT" in the white pages (or government section) of the telephone directory.		
The fire number is listed and the business number is not listed.		
C. Emergency number and business number listed under the name of the city	5	5
For credit, both the number to report a fire and the fire department business number should be listed under the community or fire district in the white pages (or government section) of the telephone directory.		
The fire number is listed and the business number is listed.		
D. If the numbers for individual fire stations are listed, DEDUCT	0	-10
For no deduction of points, the individual fire stations should not be listed in the telephone directory.		
Review of Directory Listing (TD) total:	15	20

Item 413 - "Review of Recording Device (RD)"	Earned Credit	Credit Available
A. Review of the recording device (RD):	20	20
For credit, a voice recorder should automatically record all emergency calls and the operator should be able to immediately play back any emergency call to review the conversation.		
Review of Recording Device (RD) total:	20	20

The Items "TL", "TD", and "RD" are then added together and divided by the total possible points (100 points) to determine the factor that is applied to the 2 points available for Item 414 "Credit for Telephone Service (CTS)".

414 "Credit for Telephone Service (CTS)" = 1.90 points

Item 422 - Credit for Operators (3 points)

The second item reviewed is Item 422 "Credit for Operators (CTO)". This item reviews the number of operators on duty and awake at the center to handle fire calls and other emergencies. All emergency calls including those calls that do not require fire department action are reviewed to determine the proper staffing to answer emergency calls and dispatch the appropriate emergency response. NFPA 1221, Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems, recommends that ninety-five percent of emergency calls shall be answered within 15 seconds and ninety-nine percent of emergency calls shall be answered within 40 seconds. In addition, NFPA recommends that ninety percent of emergency alarm processing shall be completed within 60 seconds and ninety-nine percent of alarm processing shall be completed within 90 seconds of answering the call.

To receive full credit for operators on duty, ISO must review documentation to show that the communication center meets NFPA 1221 call answering and dispatch time performance measurement standards. This documentation may be in the form of performance statistics or other performance measurements compiled by the 9-1-1 software or other software programs that are currently in use such as Computer Aided Dispatch (CAD) or Management Information System (MIS). If the necessary data is not available, the number of needed operators will be determined by specification criteria using a "Call Volume Matrix Table" (see the following page).

CALL VOLUME MATRIX TABLE #1 For Public Safety Answering Points that Perform Call Taking and Dispatching

Alarms per Year	Number of Needed Telecommunicators
Less than 731	1*
731 to 10,000	2
10,001 to 25,000	4**
25,001 to 50,000	5**
50,001 to 100,000	6**
100,001 to 150,000	7**
150,001 to 200,000	8**
200,001 to 250,000	9**
250,001 to 300,000	10**
Over 300,000***	11**

CALL VOLUME MATRIX TABLE #2 For Public Safety Answering Points that Perform Call Taking Without Dispatching

Alarms per Year	Number of Needed Telecommunicators
Less than 10,001	1
10,001 to 50,000	2
50,001 to 100,000	4**
100,001 to 150,000	5**
150,001 to 200,000	6**
200,001 to 250,000	7**
250,001 to 300,000	8**
Over 300,000***	9**

^{*} Communication centers that provide emergency medical dispatching (EMD) protocols need two telecommunicators on duty at all times.

^{**} Includes a supervisor in the communication center.

^{***} For every 10 additional calls (alarms) that are averaged per hour (87,600 calls per year), one additional telecommunicator is added.

To determine the score for Item 422, two sub-Items (421.A and 421.B) are summed. The details are as follows:

Item 421 - "Review of Operators (PO)"	Earned Credit	Credit Available
A. Number of operators on-duty (OD): For maximum credit, there should be 12 operators on duty at all times. There are an average of 12.00 operators on duty at the communication center.	80.00	80
B. Number of operators awake at all times (OA): For maximum credit, all operators should be awake at all times. There is an average of 12.00 operators awake at all times.	20.00	20
Review of Operators (PO) total:	100.00	100

After the items "OD" and "OA" are summed up to determine the points received for the "Review of Operators", the sum is divided by the total possible points (100 points) to determine the factor that is applied to the 3 points available for Item 422 "Credit for Operators (CTO)".

Item 422 "Credit for Operators (CTO)" = 3.00 points

Item 432 - Credit for Dispatch Circuits (5 points)

The third item reviewed is Item 432 "Credit for Dispatch Circuits (CDC)". This item reviews the dispatch circuit facilities used to transmit alarms to fire department members. A "Dispatch Circuit" is defined in NFPA 1221 as "A circuit over which an alarm is transmitted from the communications center to an emergency response facility (ERF) or emergency response units (ERUs) to notify ERUs to respond to an emergency". All fire departments (except single fire station departments with full-time firefighter personnel receiving alarms directly at the fire station) need adequate means of notifying all firefighter personnel of the location of reported structure fires. The dispatch circuit facilities should be in accordance with the general criteria of NFPA 1221. "Alarms" are defined in this Standard as "A signal or message from a person or device indicating the existence of an emergency or other situation that requires action by an emergency response agency".

There are two different levels of dispatch circuit facilities provided for in the Standard – a primary dispatch circuit and a secondary dispatch circuit. In jurisdictions that receive 730 alarms or more per year (average of two alarms per 24-hour period), two separate and dedicated dispatch circuits, a primary and a secondary, are needed. In jurisdictions receiving fewer than 730 alarms per year, a second dedicated dispatch circuit is not needed. Dispatch circuit facilities installed but not used or tested (in accordance with the NFPA Standard) receive no credit.

The score for Credit for Dispatch Circuits (CDC) is influenced by monitoring for integrity of the primary dispatch circuit. There are up to 1.5 points available for this Item. Monitoring for integrity involves installing automatic systems that will detect faults and failures and send visual and audible indications to appropriate communications center (or dispatch center) personnel. ISO uses NFPA 1221 to guide the evaluation of this item.

Additional points are available for dispatch recording facilities at the Communication Center. All alarms that are transmitted over the required dispatch circuits need to be automatically recorded (including the dates and times of transmission) to earn the maximum points in this item.

ISO's evaluation includes a review of the communication system's emergency power supplies. To receive maximum credit, two sources of power need to be provided for the operation of the communications network including dispatch circuits and its related support systems and equipment. A common arrangement is to have the primary power come from a utility distribution system and a secondary power source from an automatic starting emergency engine-generator and/or an Uninterruptible Power Supply (UPS) and Battery System – (SEPSS-Stored Emergency Power Supply Systems).

To determine the score for Item 432, four sub-items (Item 431.A, Item 431.B, Item 431.C and Item 431.D) needed to be evaluated.

The score that Wichita received for Item 432 was calculated as follows:

Item 432 - "Credit for Dispatch Circuits (CDC)"	Earned Credit	Credit Available
Item 431A - "Dispatch Circuits Provided"	40.00	40
The points are determined by prorating the value of the type of dispatch circuit using the percentage of members dependent upon each circuit.		
Item 431B - "Monitoring for Integrity of Circuit"	30.00	30
For maximum credit, the dispatch circuit should have an automatic system that will detect faults and failures and send visual and audible indications to appropriate personnel. These systems are subject to field verification and demonstration.		
Item 431C - "Dispatch Recording Facilities at Communication Center"	10.00	10
For maximum credit, all alarms that are transmitted over the required dispatch circuits need to be automatically recorded.		
Item 431D - "Emergency Power Supply"	20.00	20
For maximum credit, emergency power supplies need to be provided and regularly tested (one hour weekly, under load, with test documentation).		
Item 431E - "When no circuit is needed"	0.00	100
If all responding firefighters are in the same building as the communication center and are alerted, no dispatch circuit is needed and the maximum points are credited. However, the community does not operate in this fashion.		
Dispatch Circuits (DC) total:	100.00	100

After the Items in 431 are summed up to determine the points received for the "Credit for Dispatch Circuits (CDC)", the sum is divided by the total possible points (100 points) to determine the factor that is applied to the 5 points available for Item 432 "Credit for Dispatch Circuits (CDC)".

Item 432 "Credit for Dispatch Circuits (CDC)" = 5.00 points

The final step in determining the credit for "Receiving and Handling Fire Alarms" is to add Item 414, Item 422, and Item 432:

Item	Earned Credit	Credit Available
414. Credit for Telephone Service (CTS)	1.90	2
422. Credit for Operators (CTO)	3.00	3
432. Credit for Dispatch Circuits (CDC)	5.00	5
Item 440. Credit for Receiving and Handling Fire Alarms:	9.90	10

Fire Department

Fifty percent of a community's overall score is based upon the fire department's structure fire suppression system. ISO's field representative evaluated:

- · Engine and ladder/service vehicles including reserve apparatus
- Equipment carried
- · Distribution of fire companies
- Available and/or responding firefighters
- · Automatic Aid with neighboring fire departments
- Training

Basic Fire Flow

The Basic Fire Flow for the community is determined by the review of the Needed Fire Flows for selected buildings in the community. The following building addresses were used to determine the Basic Fire Flow:

•	7000 gpm	2828 North Governeour Street, Wichita
•	7000 gpm	1016-1060 South Oliver Street, Wichita
•	7000 gpm	4700 West 13 Street, Wichita
•	6500 gpm	2900 North Rock Road, Wichita
•	6500 gpm	213-239 South Rock Island, Wichita

The fifth largest Needed Fire Flow is determined to be the Basic Fire Flow. Since the FSRS develops a PPC for properties with a Needed Fire Flow of 3,500 gpm or less, the maximum that the Basic Fire Flow can be is 3,500 gpm. The Basic Fire Flow for Wichita has been determined to be 3500 gpm.

Item 513 - Credit for Engine Companies (10 points)

The first item reviewed is Item 513 "Credit for Engine Companies (CEC)". This item reviews the number of engine companies, their pump capacity, hose testing, pump testing and the equipment carried on the in-service pumpers. To be recognized, pumper apparatus must meet the general criteria of NFPA 1901, *Standard for Automotive Fire Apparatus* which include a minimum 250 gpm pump, an emergency warning system, a 300 gallon water tank, and hose.

The review of the number of needed pumpers considers the Basic Fire Flow; the response distance to built-upon areas; the method of operation; and the response outside the city. Multiple alarms, simultaneous incidents, and life safety are not considered.

Item 510.A. Number of Needed Engine Companies (NE):

BASIC FIRE FLOW, GPM	ENGINE COMPANIES
500 - 1,000	1
1,250 - 2,500	2
3,000 - 3,500	3

The FSRS indicates that a minimum of 28 engine companies are needed in the fire district to suppress fires in structures with a Needed Fire Flow of 3,500 gpm or less. This number is calculated as follows:

The greater of:

- a) 3 engine companies to support a Basic Fire Flow of 3500 gpm.
- b) 28 engine companies to provide fire suppression services to areas with a reasonable population of properties without a responding fire station within 1½ miles.
- c) 19 engine companies based upon the fire department's method of operation to provide a minimum two engine response to all first alarm structure fires.

There are 0 additional engine companies needed for response outside the city.

The FSRS recognizes that there are 21 engine companies in service.

For maximum credit, at least two engine companies should respond to all reported first alarms for fires in buildings (except when only one engine company is needed). The credit for engine companies has been reduced by 0.0 percent because the FSRS review deemed there is an adequate response to all reported fires in the district.

For each in-service engine, ISO reviews the pump capacity (as indicated by a pumper test), the hose (including hose testing) and the equipment carried.

For maximum credit, pumper service tests must be done annually and documented. ISO evaluates the pumper service tests using NFPA 1911, Standard for the Inspection, Maintenance, Testing and Retirement of In-service Automotive Fire Apparatus. This Standard indicates that the service tests should be conducted for:

- 20 minutes @ 100% capacity at 150 psi
- 10 minutes @ 70% capacity at 200 psi
- 10 minutes @ 50% capacity at 250 psi

Other factors such as the "overload test" are not evaluated in the FSRS and are not required for FSRS credit.

For maximum credit, hose tests must be performed annually and documented. ISO evaluates a hose testing program using NFPA 1962, Standard for the Inspection, Care, and Use of Fire Hose, Couplings and Nozzles and the Service Testing of Fire Hose.

The FSRS also reviews Automatic Aid. Automatic Aid is considered in the review as assistance dispatched automatically by contractual agreement between two communities or fire districts. That differs from mutual aid or assistance arranged case by case. ISO will recognize an Automatic Aid plan under the following conditions:

- It must be prearranged for first alarm response according to a definite plan. It is preferable to have a written agreement, but ISO may recognize demonstrated performance.
- The aid must be dispatched to reported structure fires on the initial alarm.
- The aid must be provided 24 hours a day, 365 days a year.
- The aid must offset a need in the community ISO is surveying. For example, if a community needs a ladder company and the fire department does not have one, but a neighboring community's ladder company responds by Automatic Aid agreement, credit may be available.
- The aiding ladder company must cover at least 50% of the needed ladder company Standard Response District by hydrant count in the community being graded.

FSRS Item 512.D "Automatic Aid Engine Companies" responding on first alarm and meeting the needs of the city for basic fire flow and/or distribution of companies are factored based upon the value of the Automatic Aid plan (up to 0.90 can be used as the factor). The Automatic Aid factor is determined by a review of the Automatic Aid provider's communication facilities, how they receive alarms from the graded area, inter-department training between fire departments, and the fire ground communications capability between departments.

For each engine company, the credited Pump Capacity (PC), the Hose Carried (HC), the Equipment Carried (EC) and a factor for an overweight apparatus all contribute to the calculation for the percent of credit the FSRS provides to that engine company.

After the Items in 512 are summed to determine the points received for the "In Service Total (EC)", the sum is divided by the total possible points and then multiplied by the Needed Engine Companies (NE). Next, this is multiplied by the appropriate factor representing the percent of built-upon area of the city with first alarm response of one or two engine companies. Finally, this product is multiplied by the 10 points available for Item 513 "Credit for Engine Companies (CEC)" to determine the final score for this item.

Item 513 "Credit for Engine Companies (CEC)" = 7.01 points

Item 523 - Credit for Reserve Pumpers (1 point)

The second pumper item reviewed is Item 523 "Credit for Reserve Pumpers (CRP)". This item reviews the number and adequacy of the pumpers and their equipment with one (or more in larger communities) pumper out of service. The number of needed reserve pumpers is 1 for each 8 needed engine companies determined in Item 513, or any fraction thereof. The number of reserve pumpers credited in this item will not exceed the number of needed reserve pumpers. If only one reserve pumper is needed, and more than one reserve pumper is provided in the city, only the best equipped reserve pumper will be credited. Reserve pumpers are reviewed for pump capacity, hose carried, and equipment in the same manner as described in Item 512 except that Automatic Aid reserve pumpers are not considered.

The value of the Reserve Pumper Credit (RPC) is determined by multiplying the credited Pump Capacity (PC) times the credit for the Hose Carried (HC) times the credit for the Equipment Carried (EC) times the factor for an overweight apparatus.

After the items in 521 are factored to determine the points received for each reserve pumper, the reserve pumper with the largest points is selected for the Reserve Pumper Credit (RPC). The value for RPC is added to the value in Item 512 determined above. Next, the best equipped in-service pumper is subtracted from the in-service and reserve total. The difference is then divided by the total the possible points times the Needed Engine Companies (NE). Finally, this quotient is multiplied by the 1 point available for Item 523 "Credit for Reserve Pumpers (CRP)".

Item 523 "Credit for Reserve Pumpers (CRP)" = 0.66 points

Item 532 – Credit for Pumper Capacity (5 points)

The next item reviewed is Item 532 "Credit for Pumper Capacity (CPC)". The total pump capacity available should be sufficient for the Basic Fire Flow of 3500 gpm in Wichita. The maximum needed pump capacity credited is the Basic Fire Flow of the community. The pump capacity is obtained by test at the rated pump pressure. Credit is limited to 80 percent of rated capacity if no test data is available within two years of the survey date. Less than 80 percent may be credited if other mechanical features of the apparatus indicate a generally poor mechanical condition.

The existing pump capacity (EP) represents the capacity of in-service pumpers, pumper-ladder, and pumper-service trucks that were credited in Item 513.

The reserve pump capacity (RP) is that capacity of reserve pumpers, reserve pumper-ladder, and pumper-service trucks that were credited in Item 523. One-half the capacity of permanently-mounted pumps capable of delivering at least 50 gpm at 150 psi on other apparatus, reserve pumpers and reserve pumper-ladder and reserve pumper-service trucks not credited in Items 513 or 523 is credited in this item. This capacity is expressed as "OP".

Automatic Aid pumper capacity is that capacity of pumpers credited as Automatic Aid in Item 513. The capacity credited does not exceed the percent determined by the value of the Automatic Aid plan determined in Item 512.D multiplies by the creditable pump capacity for each Automatic Aid pumper. This capacity is expressed as AAP.

The sum of the capacities determined for EP, RP, OP, and AAP is 51080 gpm. The FSRS limits the total capacity to the Basic Fire Flow of 3500 gpm. Next, this capacity is divided by the Basic Fire Flow. Finally, this factor is multiplied by the 5 points available for Item 532 "Credit for Pumper Capacity (CPC)".

Item 532 "Credit for Pumper Capacity (CPC)" = 5.00 points

Item 549 – Credit for Ladder Service (5 points)

The next item reviewed is Item 549 "Credit for Ladder Service (CLS)". This item reviews the number of response areas within the city with 5 buildings that are 3 or more stories or 35 feet or more in height, or with 5 buildings that have a Needed Fire Flow greater than 3,500 gpm, or any combination of these criteria. The height of all buildings in the city, including those protected by automatic sprinklers, is considered when determining the number of needed ladder companies. When no individual response area alone needs a ladder company, at least one ladder company is needed if buildings in the city meet the above criteria. The number and type of apparatus is dependent upon the height of buildings, Needed Fire Flow and response distance.

Response areas not needing a ladder company should have a service company. A service company is an apparatus with some or all of the equipment identified in Table 544.A (see the following pages).

The number of ladder or service companies, the height of the aerial ladder, aerial ladder testing and the equipment carried on the in-service ladder trucks and service trucks is compared with the number of needed ladder trucks and service trucks and an FSRS equipment list (Table 544 A, B, and C). Ladder trucks must meet the general criteria of NFPA 1901, Standard for Automotive Fire Apparatus to be recognized.

The number of needed ladder-service trucks is dependent upon the number of buildings 3 stories or 35 feet or more in height, buildings with a Needed Fire Flow greater than 3,500 gpm, the response distance to built-upon areas, the method of operation and the response outside the city.

The FSRS indicates that a minimum of **7** ladder companies are needed. This is calculated as follows:

7 ladder companies due to the number of buildings with a Needed Fire Flow over 3,500 gpm or 3 stories or more in height, the response distance to built-upon areas or the method of operation.

There are 0 additional ladder companies needed because 10% or less of the responses outside of the district result in a reduction of the ladder companies left in the district to 50% or less of the normal strength level.

The FSRS recognizes that there are 7 ladder companies in service.

For maximum credit, a ladder or service company should respond on first alarms to all reported fires in buildings. It was determined the ladder or service company response is to 100% of first alarm fires in buildings.

The FSRS indicates that a minimum of 5 service companies are needed. This need is calculated as follows:

5 service companies due to the number of buildings with a Needed Fire Flow over 3,500 gpm or 3 stories or more in height, the response distance to built-upon areas or the method of operation.

The FSRS recognizes that there are 5 service companies in service.

Ladders, tools and equipment normally carried on ladder trucks are needed not only for ladder operations but also for forcible entry, ventilation, salvage, overhaul, lighting and utility control.

If a ladder company is needed, the available equipment items in Table 544.A are summed to determine the points received for a Service Company, and available equipment items in Table 544.B are summed to determine the additional equipment points available for a Ladder Company. Table 544.A and 544.B points are added together to determine the total possible points available out of a possible 784 points.

Tests and sample forms for recording tests for aerial ladder and elevating platforms are described in NFPA 1911, Standard for the Inspection, Maintenance, Testing and Retirement of In-service Automotive Fire Apparatus.

If a service company is needed, the available equipment items are summed in Table 544.A. If additional ground ladders are needed for the service company, the assigned points for each available ground ladder up to 4 (from Table 544.B) are added to the points determined in Table 544.A.

All ladder company equipment, available service company equipment, available engine-ladder company equipment and available engine-service company equipment are summed. This sum is then divided by the sum of 784 points multiplied by the Needed Ladder (NL) plus 334 points multiplied by the Needed Service (NS) companies plus any points assigned for any additional ladders from Table 544.B.

Next, this factor is multiplied by the appropriate factor (A) representing the percent of builtupon area of the city with first alarm response of a ladder, service, engine-ladder or engineservice company to fires in buildings. Finally, this product is multiplied by the 5 points available for Item 549 "Credit for Ladder Service (CLS)".

Item 549 "Credit for Ladder Service (CLS)" = 3.32 points

Item 553 - Credit for Reserve Ladder and Service Trucks (1 point)

The next item reviewed is Item 553 "Credit for Reserve Ladder and Service Trucks (CRLS)". This item considers the adequacy of ladder and service apparatus when one (or more in larger communities) of these apparatus are out of service. The number of needed reserve ladder and service trucks is 1 for each 8 needed ladder and service companies that were determined to be needed in Item 540, or any fraction thereof. When 8 or less ladder and service companies are needed, and 1 or more ladder companies are needed, the reserve truck should be a ladder truck. When the number of needed reserve ladder and service trucks exceeds the number of needed reserve ladder trucks, the difference is considered as needed reserve service trucks.

The number of in-service ladder and service trucks considered out of service is determined by the number of needed reserve ladder and service trucks. The in-service ladder and service trucks credited in Item 549 having the largest number of points is what is considered as out of service. The equipment on credited reserve ladder and service trucks shall be reviewed by application of Tables 544.A, 544.B and 544.C.

The number of reserve ladder trucks credited in this item shall not exceed the number of needed reserve ladder and service trucks. If only one reserve ladder is needed, and if more than one reserve ladder or service truck is provided in the city, only the best equipped reserve ladder or service truck will be credited.

All ladder company equipment, available service company equipment, available engine-ladder company equipment and available engine-service company equipment are summed.

After the points for all reserve ladder and service equipment is determined, the reserve ladder service truck with the largest points is selected. This value is added to the value of all inservice ladder and service company equipment determined in Item 549. Next, the best equipped in-service ladder or service truck is subtracted from the in-service and reserve total. The difference is then divided by the total possible points for a ladder truck times the Needed Ladder (NL) plus the total possible points times the Needed Service (NS) plus any assigned points for any additional ladders needed from Table 544.B. Finally, this quotient is multiplied by the 1 point available for Item 553 "Credit for Reserve Ladder and Service Trucks (CRLS)".

Item 553 "Credit for Reserve Ladder and Service Trucks (CRLS)" = 0.46 points

Item 561 – Credit for Distribution (4 points)

Next, Item 561 "Credit for Distribution (CD)" is reviewed. This Item examines the number and adequacy of existing engine and ladder-service companies to cover built-upon areas of the city. The built-upon area of the city should have a fully equipped first-due engine company within 1½ miles and a fully equipped ladder-service company within 2½ miles.

To determine the Credit for Distribution, first the Existing Engine Company (EC) points and the Existing Engine Companies (EE) determined in Item 513 are considered along with Ladder Company Equipment (LCE) points, Service Company Equipment (SCE) points, Engine-Ladder Company Equipment (ELCE) points, and Engine-Service Company Equipment (ESCE) points determined in Item 549.

Secondly, a determination is made of the percentage of built upon area within 1½ miles of a first-due engine company and within 2½ miles of a first-due ladder-service company.

Item 561 "Credit for Distribution (CD)" = 1.93 points

Item 571 – Credit for Company Personnel (15 points)

Item 571 "Credit for Company Personnel (CCP)" reviews the average number of existing firefighters and company officers available to respond to reported first alarm structure fires in the city.

The on-duty strength is determined by the yearly average of total firefighters and company officers on-duty considering vacations, sick leave, holidays, "Kelley" days and other absences. When a fire department operates under a minimum staffing policy, this may be used in lieu of determining the yearly average of on-duty company personnel.

Firefighters on apparatus not credited under Items 513 and 549 that regularly respond to reported first alarms to aid engine, ladder and service companies are included in this item as increasing the total company strength.

Firefighters staffing ambulances or other units serving the general public are credited if they participate in fire-fighting operations, the number depending upon the extent to which they are available and are used for response to first alarms of fire.

Call and volunteer members (VM) are credited on the basis of the average number staffing apparatus on first alarms. Off-shift career firefighters and company officers responding on first alarms are considered on the same basis as call and volunteer personnel. For personnel not normally at the fire station, the number of responding firefighters and company officers is divided by 3 to reflect the time needed to assemble at the fire scene and the reduced ability to act as a team due to the various arrival times at the fire location when compared to the personnel on-duty at the fire station during the receipt of an alarm. The number of Public Safety Officers who are positioned in emergency vehicles within the jurisdiction boundaries may be credited based on availability to respond to first alarm structure fires. In recognition of this increased response capability the number of responding Public Safety Officers is divided by 2.

Call and volunteer firefighters and company officers assigned for on-duty shifts at fire stations on a pre-arranged schedule are considered as on duty for the proportional time that they are at the fire station.

The average number of firefighters and company officers responding with those companies credited as Automatic Aid under Items 513 and 549 are considered for either on-duty or volunteer company personnel as is appropriate. The actual number is calculated as the average number of company personnel responding multiplied by the value of AA Plan determined in Item 512.D.

The maximum creditable response of on-duty and call/volunteer firefighters is 12, including company officers, for each existing engine and ladder company and 6 for each existing service company.

Chief Officers are not creditable except when more than one chief officer responds to alarms; then extra chief officers may be credited as firefighters if they perform company duties.

The FSRS recognizes 109.00 on-duty personnel and an average of 0.00 volunteers/off-shift personnel responding on first alarm structure fires.

Item 571 "Credit for Company Personnel (CCP)" = 8.93 points

Item 581 - Credit for Training (9 points)

The final item reviewed in the Fire Department section is Item 580 "Credit for Training (CT)". This item evaluates training facilities and aids and the use made of them by the fire suppression force; company training at fire stations; classes for officers; driver and operator training; new driver and operator training; hazardous materials training; recruit training; the pre-fire planning inspection program; and the training and inspection records.

A maximum of 35% of the training evaluation is attributed to facilities, aids and use, and 65% is attributed to specialized training including the pre-fire planning inspection program.

Item 580.A.1 "Facilities and Aids "	Earned Credit	Credit Available
Drill Tower	8.00	8
For maximum credit, a 4 story drill tower should be used.		
A 5 story drill tower is available and used by the fire department.		
Fire Building (including smoke room)	8.00	8
For maximum credit, there should be a fire resistive smoke room that		
is separated from the drill tower so that training may be conducted in		
the tower and in the smoke room.		
A fire building is not available or used for training.		
Combustible Liquids Pit	5.00	5
For maximum credit, a 1,500 square foot combustible liquid pit or		
equivalent video instructing effective fire suppression of Class B fires		
should be used.		
Credit for a 1500 square foot combustible liquids pit was provided		
representing the actual size of the pit or that there is a video		
instructing effective fire suppression of Class B fires available for use		
to train the fire department personnel.		
Library and Training Manuals	2.00	2
For maximum credit, a complete library of training manuals should		
be available in the department for the membership. The library		
and manuals may include: NFPA "Fire Protection Handbook",		
"The Fire Chief's Handbook" published by Fire Engineering,		
"Managing Fire and Rescue Services" published by ICMA, Training		
manuals published by IFSTA or equivalent, and the following		
NFPA Standards, 472, 1001, 1002, 1021, 1201, 1401, 1403, 1410,		
1451, and 1620.		
Credit was given for complete training materials.		
Multi-Media Training Aids including Pump and Hydrant Cutaways	2.00	2
A slide/overhead projector and compatible multi-media aids are		
available. A movie/VCR type projector and compatible multi-media		
aids are available. A pump cutaway is available in the department		
for the membership. A hydrant cutaway is available in the		
department for the membership.		

Item 580.A.1 "Facilities and Aids " (continued)	Earned Credit	Credit Available
Training Area	10.00	10
For maximum credit, a fire department training area of at least 2.0		
acres in size should be available for single and multi-company		
drills.		
A training area of 15 acres is provided. Training is also conducted		
on streets or other areas.		
Review of Facilities and Aids (FA) total:	35.00	35
Item 580.A.2 "Use "		
a. Half-day (3 hours) drills, 8 per year (0.05 each)	0.40	0.40
For maximum credit, all members should participate in 8 half-day,	0.40	0.40
single company drills.		
single company units.		
There were an average of 8.00 single company half-day drills.		
b. Half-day (3 hours) multiple-company drills, 4 per year (0.10	0.40	0.40
each):		
For maximum credit, all members should participate in 4 half-day		
multiple company drills.		
There were an average of 4.00 multiple company drills.		
c. Night drills (3 hours), 2 per year (0.10 each):	0.20	0.20
For maximum credit, all members should participate in two 3-hour	0.20	0.20
night drills per year.		
rlight drills per year.		
There were an average of 2.00 night drills.		
Factor for "Use" subtotal -	1.00	
Average percentage participating in drills -	100%	
Factor for Use (FU):	1.00	1.0
Review of Facilities and Aids (FA) total:	35.00	35
"Facilities, Aids and Use" subtotal:	35.00	
Deduction for incomplete or missing records -	-0.00	_

Note 1: A single company drill may receive credit under a and c; a multiple-company drill may receive credit under a, b, and c.

Note 2: If the Drill Tower, Fire Building, Combustible Liquids Pit or Training Area do not achieve at least 10 points, credit will be given for the use of buildings, streets and open areas (other than formal training grounds), but not both.

After the items under Item "Facilities and Aids" are summed and the factor for "Use" is established, the credit for "Facilities, Aids and Use" is determined by multiplying the total possible points (35 points) by the factor for "Use" (up to 1.0) and subtracting any deductions for record keeping.

Facilities, Aids and Use subtotal = 35.00 points

Specialized Training	Earned Credit	Credit Available
B. Company Training	25.00	25
For maximum credit, each firefighter should receive 20 hours per month in structure fire related subjects as outlined in NFPA 1001.		
There was an average of 20.00 hours per month of company training received by company members and participation was 100% of those eligible to participate.		
0.00 points will be deducted for missing or incomplete records.		
C. Classes for Officers	15.00	15
For maximum credit, each officer should receive 2 days of leadership, management, supervisory, and incident management system training per year as outlined in NFPA 1021.		
There was an average of 2.00 days devoted to officer classes and participation is 100% of those eligible to participate.		
0.00 points will be deducted for missing or incomplete records.		
D. Driver and Operator Training	2.00	2
For maximum credit, each driver and operator should receive 4 half-day sessions of driver/operator training per year in accordance with NFPA 1002 and NFPA 1451.		
There were 4.00 half-day sessions received per year by drivers and operators and participation was 100% of those eligible to participate.		
0.00 points will be deducted for missing or incomplete records.		
E. New Driver and Operator Training	2.00	2
For maximum credit, each new driver and operator should receive 40 hours of driver/operator training per year in accordance with NFPA 1002 and NFPA 1451.		
There were 40.00 hours received per year by new drivers and operators and participation was 100% of those eligible to participate.		
0.00 points will be deducted for missing or incomplete records.		
F. Training on Hazardous Materials	1.00	1
For maximum credit, each firefighter should receive $\frac{1}{2}$ day of training for incidents involving hazardous materials in accordance with NFPA 472.		
There was 1.00 day of training received per year and participation was 100% of those eligible to participate.		
0.00 points will be deducted for missing or incomplete records.		

Specialized Training (continued)	Earned Credit	Credit Available
G. Recruit Training For maximum credit, each firefighter should receive 240 hours of structure fire related training in accordance with NFPA 1001 within the first year of employment or tenure. There were 480.00 hours received per year and participation was 100% of those eligible to participate. 0.00 points will be deducted for missing or incomplete records.	5.00	5
H. Pre-Fire Planning Inspections For maximum credit, pre-fire planning inspections of each commercial, industrial, institutional, and other similar type building (all buildings except 1-4 family dwellings) should be made twice per year by company members. Records of inspections should include up-to date notes and sketches. There are 2.50% of the buildings inspected at a yearly frequency of 1.00. Participation is 100.00%. 0.00 points will be deducted for missing or incomplete records.	0.36	15

To determine the Credit for Training, the points credited in Item 580.A though 580.H are summed.

For maximum credit, records should be kept of all training. NFPA 1401 outlines the appropriate manner in which to accomplish this. A deduction of up to 20 points (20% for each Item) is made for a lack of records. A deduction of 10% is made for incomplete records and 20% for no records for each sub-item.

A total of **0.00** points is deducted to reflect a deficiency of record keeping for Wichita.

Finally, this sum is divided by 100 and then multiplied by the 9 points available for Item 580 "Credit for Training (CT)".

Item 580 "Credit for Training (CT)" = 7.68 points

The final step in determining the Credit for Fire Department is to add the following eight components:

Item	Earned Credit	Credit Available
513. Credit for Engine Companies (CEC)	7.01	10
523. Credit for Reserve Pumpers (CRP)	0.66	1
532. Credit for Pumper Capacity (CPC)	5.00	5
549. Credit for Ladder Service (CLS)	3.32	5
553. Credit for Reserve Ladder and Service Trucks (CRLS)	0.46	1
561. Credit for Distribution (CD)	1.93	4
571. Credit for Company Personnel (CCP)	8.93	15
581. Credit for Training (CT)	7.68	9
Item 590. Credit for Fire Department:	34.99	50

Water Supply

Forty percent of a community's overall score is based on the adequacy of the water supply system. The ISO field representative evaluated:

- the capability of the water distribution system to meet the Needed Fire Flows at selected locations up to 3,500 gpm.
- size, type and installation of fire hydrants.
- inspection and condition of fire hydrants.

Item 616 - Credit for Supply System (35 points)

The first item reviewed was Item 616 "Credit for Supply System (CSS)". This item reviews the rate of flow that can be credited at each of the Needed Fire Flow test locations considering the supply works capacity, the main capacity and the hydrant distribution. The lowest flow rate of these items is credited for each representative location. A water system capable of delivering 250 gpm or more for a period of two hours plus consumption at the maximum daily rate at the fire location is considered minimum in the ISO review.

To determine the score for Item 616 "Credit for Supply System (CSS)", three sub-items are evaluated (Item 612 "Supply Works Capacity", Item 613 "Main Capacity" and Item 614 "Hydrant Distribution").

Where there are 2 or more systems or services distributing water at the same location, credit is given on the basis of the joint protection provided by all systems and services available.

The supply works capacity is calculated for each representative Needed Fire Flow test location, considering a variety of water supply sources. These include public water supplies, emergency supplies (usually accessed from neighboring water systems), suction supplies (usually evidenced by dry hydrant installations near a river, lake or other body of water), and supplies developed by a fire department using large diameter hose or vehicles to shuttle water from a source of supply to a fire site. The result is expressed in gallons per minute (gpm).

The normal ability of the distribution system to deliver Needed Fire Flows at the selected building locations is reviewed. The results of a flow test at a representative test location will indicate the ability of the water mains (or fire department in the case of fire department supplies) to carry water to that location.

The hydrant distribution is reviewed within 1,000 feet of representative test locations measured as hose can be laid by apparatus. Credit is allowed up to 1,000 gpm for each hydrant within 300 feet of the location, 670 gpm for hydrants within 301 to 600 feet of the location and 250 gpm for hydrants within 601 to 1,000 feet of the location. Credit may be reduced when hydrants do not have a pumper outlet and/or two or more hose outlets. If a hose diameter greater than $2\frac{1}{2}$ inch is carried by all in-service pumpers, the hydrant distribution credit may be greater due to the reduced friction loss in the larger diameter hose.

For maximum credit, the Needed Fire Flows should be available at each location in the district. Needed Fire Flows of 2,500 gpm or less should be available for 2 hours; and Needed Fire Flows of 3,000 and 3,500 gpm should be obtainable for 3 hours.

Item 616 "Credit for Supply System (CSS)" = 34.23

Item 621 – Credit for Hydrants (2 points)

The second item reviewed is Item 621 "Credit for Hydrants (CH)". This item reviews the number of fire hydrants of each type compared with the total number of hydrants.

For maximum credit, all hydrants should have a pumper outlet, 6 inch or larger branch connection, uniform size operating nut and should operate in a uniform direction in accordance with AWWA C-502 Standard for Dry-Barrel Fire Hydrants or AWWA C-503 Standard for Wet-Barrel Fire Hydrants.

For maximum credit, all suction supply points should be equipped with a dry hydrant with a 6 inch or larger pipe and fittings, a minimum number of 90 degree elbows (preferably no more than two), and suction screen placement so that the dry hydrant will deliver the design capacity (usually 1,000 gpm) as specified in NFPA 1142, *Standard on Water Supplies for Suburban and Rural Fire Fighting.*

There are a total of 11798 hydrants in the city.

620. Hydrants, - Size, Type and Installation	Earned Credit	Credit Available
A. With a 6 -inch or larger branch and a pumper outlet with or without 2½ -inch outlets There are 11649 hydrants that have a 6 -inch or larger branch and a pumper outlet.	98.74	100
B. With a 6 -inch or larger branch and no pumper outlet but two or more 2½ -inch outlets, or with a small foot valve, or with a small barrel There are 8 hydrants that have a 6 -inch or larger branch but no pumper outlet, or have a small foot valve or with a small barrel.	0.05	75
C. With only a 2½ -inch outlet There are 0 hydrants with only a 2½ -inch outlet.	0.00	25
D. With less than a 6 -inch branch There are 141 hydrants with less than a 6 -inch branch connection.	0.30	25
E. Flush Type There are 0 hydrants that are of the flush type.	0.00	25
F. Cistern or suction point There are 0 locations that are considered a cistern and/or a suction point.	0.00	25
Total	99.09	100

Note 1: 2 points are deducted for each 10 percent of the hydrants that are not operating in a uniform direction of the majority, or with an operating nut different from the majority.
Of the 11798 hydrants that were reviewed, 0% did not operate in the direction of the majority and 0% had a different size operating nut.

Note 2: 10 points are deducted if more than one type hose thread is used for pumper or hose outlets. Of the 11798 hydrants that were reviewed, none had a different hose thread than the majority. There were no points deducted for this item.

To determine the "Credit for Hydrants (CH)", the points credited in Item 620.A though 620.F are summed, including any deductions. The sum is divided by 100 and then multiplied by the 2 points available for Item 621 "Credit for Hydrants (CH)".

Item 621 "Credit for Hydrants (CH)" = 1.98

Item 630 – Credit for Inspection and Condition (3 points)

The third item reviewed is Item 630 "Credit for Inspection and Condition (CIC)". This item reviews the fire hydrant inspection frequency, the completeness of the inspections and the condition of hydrants. Inspection and condition of hydrants should be in accordance with AWWA M-17, Installation, Field Testing and Maintenance of Fire Hydrants.

A. Inspection (HI):

The frequency of inspection is the average time interval between the 3 most recent inspections.

Frequency of Inspections	Points
½ year	100
1 year	80
2 years	65
3 years	55
4 years	45
5 years or more	40

Note:

The points for inspection frequency are reduced by 10 points if the inspections are incomplete or do not include a flushing program. An additional reduction of 10 points are made if hydrants are not subjected to full system pressure during inspections. If the inspection of cisterns or suction points does not include actual drafting with a pumper, or back-flushing for dry hydrants, 40 points are deducted.

B. Condition (HF):

A factor (HF) is determined from the following list of conditions according to the actual condition of hydrants examined compared with the total number examined during the survey:

Condition	Factor
Standard (no leaks, opens easily, conspicuous, well located for use by pumper)	1.0
Usable (with some defects and/or impediments to use)	0.5
Not Usable	0.0

For maximum credit, all hydrants should be inspected twice a year. The inspection should include operation of the fire hydrant, a test for leaks (using domestic pressure), and a flushing of the hydrant. Records should be kept of inspections.

Water System: Wichita Water Utilities

Item 630.A "Inspection (HI):"		Time Interval
Most recent inspection was May 01, 2007		
1 st prior inspection was May 01, 2006		1 year
2 nd prior inspection was May 01, 2005		1 year
Review of Inspection (HI):	Earned Credit	Credit Available
	80	100

For maximum credit, all hydrants should be conspicuous, well located for use by a pumper and in good condition. There were 186 hydrants examined in this FSRS item.

Item 630.B "Condition (HF):"		Maximum Factor
Standard:		1.0
There were 186 hydrants considered in standa	rd condition.	
Usable:		0.5
There were 0 hydrants considered in usable condition.		
Not Usable:		0.0
There were 0 hydrants considered not usable.		
Review of Condition (HF):	Condition Factor (HF)	Maximum Factor
	1.00	1.0

To determine the "Credit for Inspection and Condition (CIC)", the points credited in Item 630.A are multiplied by the Condition Factor from Item 630.B. The product is divided by 100 and then multiplied by the 3 points available for Item 631 "Credit for Inspection and Condition (CIC)".

Item 631 "Credit for Inspection and Condition (CIC)" = 2.40

The final step in determining the credit for Water Supply is to add Item 616, Item 621, and Item 631:

Item	Earned Credit	Credit Available
616. Credit for Supply System (CSS)	34.23	35
621. Credit for Hydrants (CH)	1.98	2
631. Credit for Inspection and Condition (CIC)	2.40	3
Item 640. Credit for Water Supply:	38.61	40

Divergence = -5.31

The Divergence factor mathematically reduces the score based upon the relative difference between the fire department and water supply scores. The factor is introduced in the final equation.

Summary of Public Protection Classification Review

Completed by ISO

for

Wichita

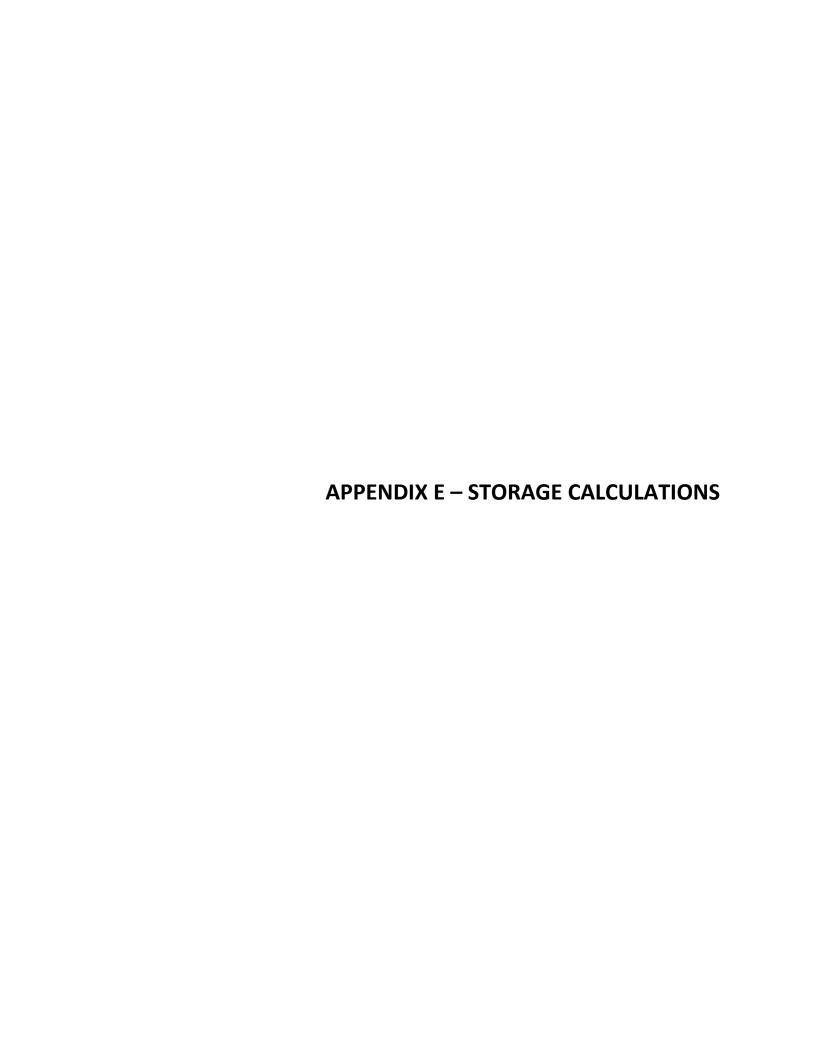
FSRS Item	Earned Credit	Credit Available
Receiving and Handling Fire Alarms 414. Credit for Telephone Service 422. Credit for Operators 432. Credit for Dispatch Circuits	1.90 3.00 5.00	2 3 5
440. Credit for Receiving and Handling Fire Alarms	9.90	10
Fire Department 513. Credit for Engine Companies 523. Credit for Reserve Pumpers 532. Credit for Pumper Capacity 549. Credit for Ladder Service 553. Credit for Reserve Ladder and Service Trucks 561. Credit for Distribution 571. Credit for Company Personnel 580. Credit for Training	7.01 0.66 5.00 3.32 0.46 1.93 8.93 7.68	10 1 5 5 1 4 15 9
590. Credit for Fire Department	34.99	50
Water Supply 616. Credit for Supply System 621. Credit for Hydrants 631. Credit for Inspection and Condition 640. Credit for Water Supply Divergence	34.23 1.98 2.40 38.61 -5.31	35 2 3 40
Total Credit	78.19	100

Community Classification = 3

If the individual scores Wichita achieved for Receiving and Handling Fire Alarms; Fire Department; and Water Supply were translated into a 100 point scale instead of the (10, 50 and 40) points actually used, the relative Fire Suppression Rating Schedule classification for each of these sections would be:

Receiving and Handling Fire Alarms: a (relative) Class 1

Fire Department: a (relative) Class 4
Water Supply: a (relative) Class 1



Calculation 6.1

Northeast Pressure Zone Storage Evaluation

Total storage = Hess Reservoir storage allocation + Webb Reservoir storage + Northeast Tower storage, where

Hess Reservoir storage allocation = (NEPZ maximum day demand / system max day demand) x Hess Reservoir storage Northeast pressure zone maximum day demand = 5.7 MGD

2015 system maximum day demand = 78.0 MGD

Hess Reservoir storage = 35.1 MG

Therefore, 2.57 MG = $(5.7 \text{ MGD} / 78.0 \text{ MGD}) \times 35.1 \text{ MG}$

Webb Reservoir storage = 10.0 MG Northeast Tower storage = 1.0 MG

Therefore, 13.6 MG = 2.6 + 10.0 MG + 1.0 MG

Minimum storage requirement = Equalization storage + Fire storage, where

Equalization = Equalization factor x (maximum day demand x 1 day)

Equalization factor = 0.12

Maximum day demand = 5.7 MGD

Fire storage = (3,500 gpm x (60 min/hour)) x 3 hours

Therefore, 1.31 MG = 0.68 + 0.63 MG

Effective Storage

City staff indicated, based on historical operation of Webb Rd PS for the Northeast pressure zone, a minimum water level of 7 ft is required to start a pump; therefore, the effective storage at Webb Reservoir is determined as the volume of water above 7 ft. The effective storage for the Northeast pressure zone is determined by the following:

Northeast Pressure Zone Effective Storage = Hess Reservoir Allocation + Webb Rd Reservoir Effective Storage

Hess Reservoir Allocation = 2.57 MG

Webb Reservoir Effective Storage = (head range - minimum operating level) x Volume per foot

Head Range = 20 ft

Total Reservoir Volume = 10.0 MG

Volume per foot = 0.5 MG/ft = 10.0 MG / 20 ft

Therefore, Webb Reservoir Effective Storage = 6.5 MG = (20 ft - 7 ft) x (0.5 MG/ft)

Therefore, Northeast Pressure Zone Effective Storage = 9.07 MG = 2.57 MG + 6.5 MG

9.07 MG out of the 13.6 MG of total storage for the Northeast pressure zone is termed effective. The Northeast Tower is not termed effective because it is out of service.

Emergency Storage

If effective storage is greater than the minimum required storage, a surplus exists and the difference can be allocated for emergency storage, or portion thereof at the City's discretion.

Northeast Pressure Zone Effective storage = 9.07 MG

Minimum required storage = 1.31 MG

Therefore, Emergency Storage = Surplus = 7.76 MG MG = 9.07 MG - 1.31 MG

Since 9.07 MG > 1.31 MG, a storage surplus of 7.76 MG exists. The surplus can be allocated for emergency storage or any portion thereof designated by the City.

Duration of Emergency Storage under Maximum Day Demand

Duration = emergency storage / maximum day demand, where

Total emergency storage allocation = 7.76 MG

Maximum day demand (Northeast pressure zone) = 5.7 MGD

Emergency condition = loss of power at Webb Rd PS and 37th St BPS.

Therefore, 1.35 days (or 32.4 hours) = 7.76 MG / 5.7 MGD

There are 1.35 days of emergency storage from Hess Reservoir and Webb Rd Reservoir combined. Individually, Hess Reservoir provides 0.38 days (9.2 hours) of emergency storage and Webb Reservoir provides 0.97 days (23.2 hours) of emergency storage.

Hess Reservoir Emergency Storage allocation = 0.38 days = $(2.57 \text{ MG} / 9.07 \text{ MG}) \times 1.35$ hours Webb Reservoir Emergency Storage allocation = 0.97 days = $(6.5 \text{ MG} / 9.07 \text{ MG}) \times 1.35$ hours

Alternative Example to Lower Storage in Webb Reservoir

If the City did not rely on the Hess Reservoir emergency storage allocation and designated 12 hours (0.5 days) worth of emergency storage at Webb Reservoir for the Northeast pressure zone, then:

Minimum required storage = Equalization + Fire + Designated Emergency
Equalization = 0.68 MG
Fire = 0.63 MG
Designated Emergency = duration x maximum day demand
Therefore, 2.85 MG = 0.5 days x 5.7 MGD

Therefore, Minimum required storage = 4.16 MG = 0.68 MG + 0.63 MG + 2.85 MG

Equivalent water level for minimum required storage = 8.32 ft = (4.16 MG / 10.0 MG) x 20 ft

Therefore, the City could operate Webb Reservoir between 7.0 ft and 15.32 ft and this head range would cover equalization, fire, and 0.5 days worth of emergency storage under a maximum day demand of 5.7 MGD.

City of Wichita, Kansas Burns and McDonnell

Calculation 6.2 East Pressure Zone Storage Evaluation

Total storage = Hess Reservoir storage allocation (assumes Pump MLP-1 is designated for Northeast pressure zone service)

Hess Reservoir storage allocation = (EPZ maximum day demand / system max day demand) x Hess Reservoir storage

East pressure zone maximum day demand = 11.3 MGD

2015 system maximum day demand = 78.0 MGD

Hess Reservoir storage = 35.1 MG

Therefore, 5.1 MG = (11.3 MGD / 78.0 MGD) x 35.1 MG

Minimum storage requirement = Equalization storage + Fire storage, where

Equalization = Equalization factor x (maximum day demand x 1 day)

Equalization factor = 0.18

Maximum day demand = 11.3 MGD

Fire storage = $(3,500 \text{ gpm x } (60 \text{ min/hour})) \times 3 \text{ hours}$

Therefore, 2.66 MG = 2.03 MG + 0.63 MG

Effective Storage

The total storage of 5.1 MG in the Hess Reservoir system allocated to the East pressure zone is effective storage.

Therefore, Effective storage = Available Storage = 5.1 MG

Emergency Storage

If effective storage is greater than the minimum required storage, a surplus exists and the difference can be allocated for emergency storage, or portion thereof at the City's discretion.

East pressure zone effective storage = 5.1 MG

Minimum storage requirement = 2.7 MG

Therefore, 2.44 MG = 5.1 MG - 2.66 MG

Since 5.1 MG > 2.66 MG, a storage surplus of 2.44 MG exists in the Hess Reservoir system. The surplus amount can be allocated for emergency service or any portion thereof desired by the City.

Duration of Emergency Storage under Maximum Day Demand

Duration = emergency storage / maximum day demand, where

Emergency storage = 2.44 MG

Maximum day demand = 11.3 MGD

Emergency condition = loss of power at Webb Rd PS and Southeast BPS.

Therefore, 0.21 days (or 5.2 hours) = 2.44 MG / 11.3 MGD

City of Wichita, Kansas Burns and McDonnell

Calculation 6.3 Hess Pressure Zone Storage Evaluation

Total storage = Hess Reservoir storage allocation + Woodlawn Tower + Roosevelt Tower

Hess Reservoir storage allocation = (HPZ + WMPZ maximum day demand / system max day demand) x Hess Reservoir storage

Hess pressure zone + West Maple pressure zone maximum day demand = 60.9 MGD = 60.8 MGD + 0.06 MG

2015 system maximum day demand = 78.0 MGD

Therefore, 27.4 = ((60.9 MGD / 78.0 MGD) x 35.1 MG)

Woodlawn Tower = 2.0 MG Roosevelt Tower = 2.0 MG

Hess Reservoir storage = 35.1 MG

Therefore, 31.4 MG = 27.4 + 2.0 MG + 2.0 MG

Minimum storage requirement = Equalization storage + Fire storage, where

Equalization = Equalization factor x (maximum day demand x 1 day)

Equalization factor = 0.14Maximum day demand = 60.8 MGDFire storage = (7,000 gpm x (60 min/hour)) x 4 hours

Therefore, 10.2 MG = 8.5 MG + 1.7 MG

Effective Storage

City staff indicated, based on historical operation of Hess HSPS, pumps must be started above 7 ft and could be pumped down to a minimum of 4 ft before they lose suction. For the purposes of this evaluation, it is assumed pumps at Hess HSPS are in service above a water level of 7 ft; therefore, effective storage is considered the volume of water above 4 ft. Effective storage for Hess pressure zone is determined by the following:

Hess Reservoir Effective Storage = (head range - minimum operating level) x Volume per foot

Head Range = 15 ft

Total Reservoir Volume = 35.1 MG

Volume per foot = 2.34 MG/ft = 35.1 MG / 15 ft

Woodlawn and Roosevelt Tower are not termed effective storage because they cannot maintain adequate pressure across the entire Hess pressure zone at the bottom elevation of the tank bowl under fire flow conditions.

Therefore, Hess Reservoir Effective Storage = 25.74 MG = (15 ft - 4 ft) x (2.34 MG/ft)

25.74 MG out of the 31.4 MG of total storage for Hess pressure zone is termed effective.

Emergency Storage

If effective storage is greater than the minimum required storage, a surplus exists and the difference can be allocated for emergency storage, or portion thereof at the City's discretion.

Hess pressure zone effective storage = 25.74 MG Minimum storage requirement = 10.2 MG

Therefore, 15.54 MG = 25.74 MG - 10.2 MG

Since 25.74 MG > 10.2 MG, a storage surplus of 15.54 MG exists in the Hess Reservoir system. The surplus can be allocated for emergency service or any portion thereof desired by the City.

Emergency Storage Duration

Duration = emergency storage / maximum day demand, where

Emergency storage = 15.54 MG

Maximum day demand = 60.9 MGD

Emergency condition = loss of power at Hess HSPS with no interruption to the treatment process treating and supplying the reservoir system.

Therefore, 0.25 days (or 6.1 hours) = 15.54 MG / 60.9 MGD

Additional Comments:

1. Hess HSPS has backup power estimated to allow 4 pumps in operation. There are 4 generators rated for 2,000 kW, for a total of 8,000 kW. Assuming all generators serve a common bus, which then serves all 8 pumps, it is estimated each pump requires approximately 1,700 kW for a total pumping capacity of approximately 115.2 MGD. The rated treatment capacity of the Central WTP is 130 MGD, but the operational capacity is less and potentially limited by hydraulic bottlenecks, backwashing capability, and/or filter loading; therefore, the storage evaluation includes a pumping capacity with backup power of 97.2 MGD from 3 pumps under emergency conditions to further diminish the effect of the actual operational capacity of the treatment process.

City of Wichita, Kansas

Burns and McDonnell

Calculation 6.4 Storage Evaluation for Hess, East, and West Maple Pressure Zones

Total storage = Hess Reservoir storage allocation + Woodlawn Tower + Roosevelt Tower

Hess Reservoir storage allocation = (maximum day demand / system max day demand) x Hess Reservoir storage

Hess, East, West Maple maximum day demand = 72.2 = 60.8 MGD + 11.3 MGD + 0.06 MGD

2015 system maximum day demand = 78.0 MGD

Hess Reservoir storage = 35.1 MG

Therefore, $32.5 \text{ MG} = (72.2 \text{ MGD} / 78.0 \text{ MGD}) \times 35.1 \text{ MG}$

Woodlawn Tower = 2.0 MG Roosevelt Tower = 2.0 MG

Therefore, 36.5 = 32.5 MG + 2.0 MG + 2.0 MG

Minimum storage requirement = Equalization storage + Fire storage, where

Equalization = Equalization factor x (maximum day demand x 1 day)

Equalization factor = 0.13

Maximum day demand = 72.3 MGD

Fire storage = (7,000 gpm x (60 min/hour)) x 4 hours

Therefore, 11.1 MG = 9.4 MG + 1.7 MG

Effective Storage

Effective storage in the Hess Reservoir system is as determined in Calculation 6.3.

Hess Reservoir Effective Storage = $25.74 \text{ MG} = (15 \text{ ft} - 4 \text{ ft}) \times (2.34 \text{ MG/ft})$

25.74 MG out of the 36.5 MG of total storage for the Hess, East, and West Maple pressure zones is termed effective.

Emergency Storage

If effective storage is greater than the minimum required storage, a surplus exists and the difference can be allocated for emergency storage, or portion thereof at the City's discretion.

Hess, East, and West Maple pressure zones effective storage = 25.74 MG

Minimum storage requirement = 11.1 MG

Therefore, 14.64 MG = 25.74 MG - 11.1 MG

Since 25.74 MG > 11.1 MG, a storage surplus of 14.64 MG exists in the Hess Reservoir system. The surplus can be allocated for emergency service or any portion thereof desired by the City.

Emergency Storage Duration

Duration = emergency storage / maximum day demand, where

Emergency storage = 14.64 MG

Maximum day demand = 72.2 MGD

Worst Case condition = loss of treatment capability

Therefore, 0.20 days (or 4.8 hours) = 14.64 MG / 72.2 MGD

Alternative Example to Lower Storage in Hess Reservoir

If the City designated 2 hours (0.083 days) of emergency storage at Hess Reservoir system for the Hess, East, and West Maple pressure zones, based on the maximum day demand of 72.2 MGD, and restored the vacuum priming system then

Minimum storage requirement = Fire + Equalization + Designated Emergency

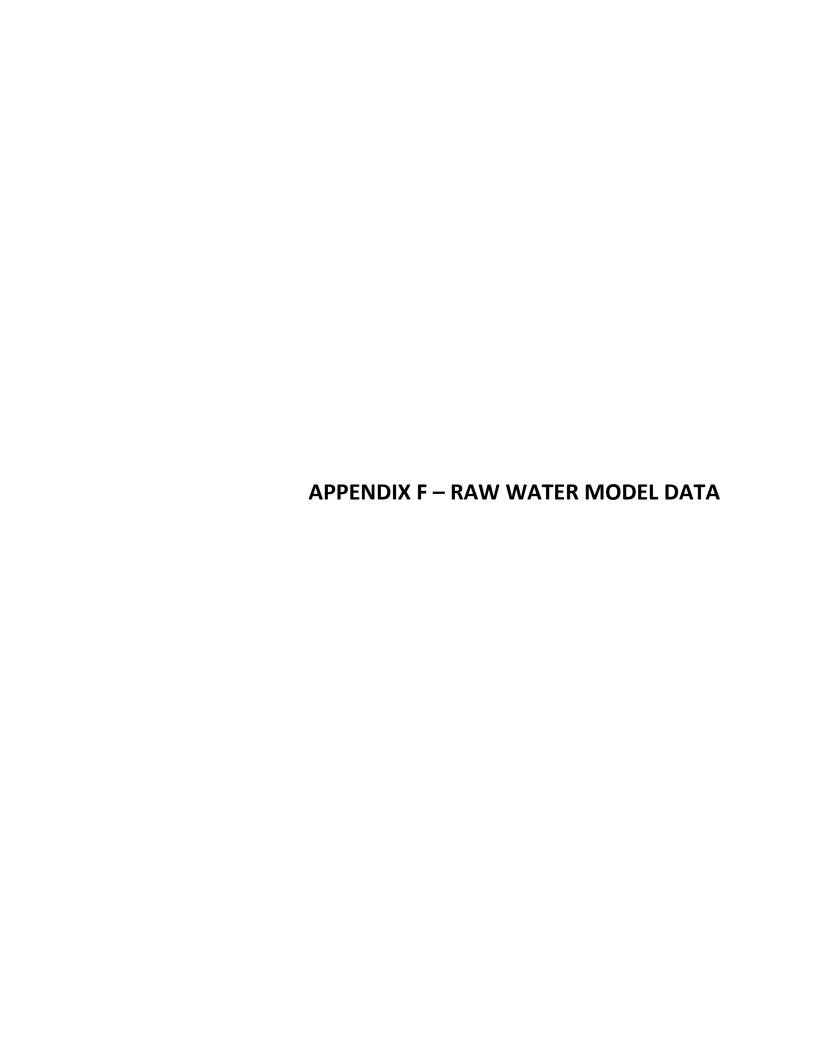
Equalization + Fire + 0.2 days Emergency = 17.12 MG = 9.4 MG + 1.7 MG + (0.083 days x 72.2 MGD)

Then, Equivalent water level for minimum storage requirement = 7.32 ft = $(17.12 \text{ MG} / 35.1 \text{ MG}) \times 15 \text{ ft}$

The operating range in Webb Reservoir between 4.0 ft and 11.32 ft covers equalization, fire, and 2 hours of emergency storage under a maximum day demand of 72.2 MGD if the vacuum priming system is restored and the pumps are capable of starting above a water level of 4.0 ft. If the vacuum priming system is not restored, then the recommendation is to maintain as much storage as possible under normal conditions.

City of Wichita, Kansas

Burns and McDonnell



						On	Off	On	Off	Pump	Тор	Well	Top of 18" Casing		Dist. From F.F. to CL		Calc		Water Pumping		Column Pipe
WELL	GPM	Static	Pumping	D.D	S.C	Deep	Deep	Shallow	Shallow	Intake	Screen	Static PSI	Elevation	F.F. El.	Discharge	WELL		Discharge El.	El.	Flow	Length (ft)
MR-1	1171	30.17	81.86	51.69	22.65	29.48	23.91				109	10			Ì	MR-1		1431	1349	1171	
MR-2	779	37.6	96.64	59.04	13.19	58.12	36.09	19.21	19.2	156	184	14	1434.5	1431.3	4.6	MR-2	1278	1436	1338		157
M-3	1304	36.18	80.37	44.19	29.51	35.64	33.96				124	17				M-3		1431	1351	1304	
MR-4	952	37.69	75.81	38.12	24.97	53.1	35.76	21.95	22	156	133	18	1431.2	1428.5	4.6	MR-4	1275	1433	1355		158
M-5	1153	37.37	101.92	64.55	17.86	30.8	30.44				181	13				M-5		1433	1331	1153	
MR-6	1000	34.45	67.45	33	30.30	48.35	35.61	37.08	33.17	156	69	11.5	1435.9	1432.7	4.6	MR-6	1280	1437	1368		157
M-7	1276	32.4	77.31	44.91	28.41	54.77	31.9	30.94	31.11		122	20				M-7		1428	1351	1276	
MR-8	1090	28.61	60.52	31.91	34.16	41.43	27.44	27.53	27.42	106	149	13	1425.8	1422.6	4.6	MR-8	1320	1427	1365		107
M-9	845	25.38	99.41	74.03	11.41	22.35	22.47				99	18				M-9		1417	1318	845	
MR-10	983	29.96	73.48	43.52	22.59	41.25	29.67	30.78	27.72	106	84	17	1425.9	1422.7	4.6	MR-10	1320	1427	1352		107
MR-11	1034	28.96	61.39	32.43	31.88	41.06	27.54	26.57	26.85	106	170	11	1422.8	1419.6	4.6	MR-11	1317	1424	1361		107
M-12	1052	26.9	58.03	31.13	33.79	29.91	24.82				120	19				M-12		1416	1358	1052	
MR-13	857	23.3	50.03	26.73	32.06	36.32	24.69	25	24.63	78.5	84	14	1419.2	1416	4.6	MR-13	1341	1421	1369		80
MR-14	1034	29	68.65	39.65	26.08	45.87	26.59	28.06	26.18	106	133	12	1419.2	1416	4.6	MR-14	1313	1421	1351		107
M-15	1111	27.21	69.48	42.27	26.28	24.3	24.95				145	13				M-15		1415	1346	1111	ļ
M-16	1153	27.02	65.95	38.93	29.62	26.11	24.54				116	27				M-16		1410	1344	1153	<u> </u>
M-17	937	24.72	56.65	31.93	29.35	23.88	24.07				125	15				M-17		1408	1351	937	
MR-18	1090	23.04	49.75	26.71	40.81	29.22	20.55	22.07	20.41	136	62	17	1408.0	1404.83	4.6	MR-18	1272	1409	1358		137
MR-19	487	25.16	87.49	62.33	7.81	39.95	25.14	25.54	25.43	119	124	30	1403.4	1402.5	4.6	MR-19	1284	1407	1316		123
MR-20	740	25	54.59	29.59	25.01	31.79	23.41	24.34	23.66	135	80	21	1401.2	1398	4.6	MR-20	1266	1403	1347	1000	136
M-21	1200	21.57	74.19	52.62	22.81	21.89	20.68				57	27				M-21	1000	1392	1318	1200	100
MR-22 MR-23	1241	25.41	65.89	40.48	30.66	31.84	24.54	24.44	24.8	135	61	25	1397.2	1394	4.6	MR-22	1262	1399	1331		136 136
	659	27.6	49.11	21.51	30.64	32.27	26.23	27.21	25.89	135	69	25	1396.2	1393	4.6	MR-23	1261	1398	1347	4476	136
M-24	1176	21.52	62.78	41.26	28.50	14.69	14.76				68	32				M-24		1390	1327	1176	
M-25 MR-26	895 952	20.35	46.04	25.69	34.84	19.61	19.33	21.04	21.00	106	109	29	1406.3	1402.20	4.6	M-25 MR-26	1200	1384	1338	895	100
M-27	952 810	23.89	54.01 51.94	30.12	31.61	37.18 22.17	21.85	21.84	21.99	106	74 78	17 18	1406.2	1403.26	4.6	M-27	1300	1408	1352	810	108
M-28	769	20.99 21.88	51.94	30.95 36.23	26.17 21.23	21.84	21.41	 			78 88	25			ŀ	M-28		1391 1393	1339 1335	769	+
171-20	709	21.00	20.11	30.23	21.25	21.04	22.12	l	l	l	00	23				IVI-20		1999	1333	709	

With in 2 ft or at Pump intake.

With in 2 ft or at Top Screen

						On	Off	On	Off	Pump	Тор	Well	Top of 18" Casing		Dist. From F.F. to CL		Calc		Water Pumping		Column Pipe
WELL	GPM	Static	Pumping	D.D	S.C	Deep	Deep	Shallow	Shallow	Intake	Screen	Static PSI	Elevation	F.F. El.	Discharge	WELL		Discharge El.	El.	Flow	Length (ft)
M-29	508	23.58	74.75	51.17	9.93	18.87	20.42				95	30				M-29		1393	1318	508	
M-30	638	21.02	50.1	29.08	21.94	18.45	19.54				161	37				M-30		1389	1339	638	
M-31	1153	20.42	28.14	7.72	149.35	19.84	20.21				57	31				M-31		1388	1360	1153	
M-32	967	20.45	69.32	48.87	19.79	18.71	19.01				103	37				M-32		1385	1316	967	
M-33	731	19.87	90.91	71.04	10.29	16.43	16.06				68	30				M-33		1383	1292	731	
MR-34	909	20.82	98.16	77.34	11.75	16.83	17.05				100	27				MR-34		1384	1286	909	
M-35	923	21.58	42.96	21.38	43.17	20.32	20.62				65	31				M-35		1383	1340	923	
MR-36	810	24.2	58.49	34.29	23.62	26.35	19.81	18.82	19.2		108	30				MR-36		1383	1325	810	
M-37	652	15.58	62.42	46.84	13.92	24.93	15.95	16.07	16.09		114	34				M-37		1375	1313	652	
M-38	722	17.39	58.08	40.69	17.74	23.94	19.11	23.14	23.21		93	35				M-38		1375	1317	722	
M-39	845	16.48	36.34	19.86	42.55	15.76	14.98	16.43	15.84		85	36				M-39		1372	1336	845	
M-40	714	16.42	50.49	34.07	20.96	15.94	14.81	14.5	14.54		92	39				M-40		1371	1321	714	
M-41	1176	21.59	117.35	95.76	12.28	27.11	27.17	12.72	12.75		196	9				M-41		1426	1309	1176	
MR-42	714	26.54	89.53	62.99	11.34	65.79	24.87	16.12	16.19	155	211	7	1431.2	1428.06	4.6	MR-42	1276	1433	1342		156
MR-43	1138	18.67	47.83	29.16	39.03	27.89	17.33	23.57	16.71	78	57	9	1431.2	1428.06	4.6	MR-43	1353	1433	1383		79
MR-44	1000	16.2	45.43	29.23	34.21	26.04	14.28	13.23	13.27	62	66	9	1431.2	1428.06	4.6	MR-44	1369	1433	1386		63
MR-45	845	17.34	45.53	28.19	29.98	25.16	15.02	13.48	13.8	135	74	10	1426.8	1423.6	4.6	MR-45	1292	1428	1381		136
M-46	402	19.81	104.3	84.49	4.76	32.2	16.68	13.64	13.76		64	28.5				M-46		1423	1318	402	
MR-47	852	17.88	57.87	39.99	21.31	24.71	19.77	16.6	16.47	105	59	13	1423.7	1420.5	4.6	MR-47	1319	1425	1366		106
MR-48	833	25.94	47.16	21.22	39.26	32	24.29	23.2	23.36	78	81	21	1409.7	1406.5	4.6	MR-48	1332	1411	1363		79
M-49	954	22.48	49.66	27.18	35.10	23.2	21.09	23.84	24.22		123	24				M-49		1404	1354	954	
MR-50	882	24.94	68.65	43.71	20.18	47.43	24.12	23.85	24.21	105	153	20	1410.2	1408.9	4.6	MR-50	1305	1413	1342		108
MR-51	561	20.37	60.76	40.39	13.89	25.84	20.81	12.04	12.19	135	91		1411.0	1408.5	4.6	MR-51	1276	1413	1350		137
M-52	659	11.59	23.39	11.8	55.85	12.87	13.03				30	15				M-52		1406	1383	659	
M-53	508	11.44	21.51	10.07	50.45	12.83	9.36				36	17.5				M-53		1403	1381	508	<u> </u>
M-54	967	13.85	29.93	16.08	60.14	12.83	14.54				38	18.5				M-54		1403	1373	967	
MR-55	1034	15.31	21.24	5.93	174.37	15.13	13.7	15.07	13.67	39	29	17.5	1407.2	1404	4.6	MR-55	1368	1409	1386		40
MR-56	1052	15.96	41.5	25.54	41.19	20.06	16.88	12.97	13.01	73	79	18	1426.2	1423	4.6	MR-56	1353	1428	1385		74
TOTALS	49847				31.48											TOTALS					

With in 2 ft or at Pump intake.

With in 2 ft or at Top Screen

	Date:	5/17	7/2016	5/1	7/2016	5/1	7/2016	5/1	7/2016	5/18/	2016	5/18/2016		5/19/2016	
	Time:		46 AM		50 PM		17,2010 LO PM	·	30 PM	8:33			07 AM		33 AM
Opera	ating Condtion:		nd Production				nd Production		duction with the flow	Recharge and Produ			13 MGD Wellfield		18 MGD Well Field
	nto the Plant (MGD):		6.20		5.50		3.00		13.00	42.			2.70		8.00
	Flow Rate (MGD):		30	3	36.9		30		30	2	9		29		30
Discharg	ge Pressure (psi):		65		65		65		65	64	.5	6	54.5	6	54.9
Chenney Su	urge Tank Level (ft):	0	0.05		0		0		0	()		0		0
P	Pump No.	ON/OFF	Pump Speed	ON/OFF	Pump Speed	ON/OFF	Pump Speed	ON/OFF	Pump Speed	ON/OFF	Pump Speed	ON/OFF	Pump Speed	ON/OFF	Pump Speed
	1	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%
	2	ON	97%	ON	97%	ON	97%	ON	97%	ON	95%	ON	95%	ON	97%
	3	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%
	4	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%
D424 EL	5 P-+ (NACP):	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%	OFF	0%
	ow Rate (MGD):		5.2		4.4		6.1		7.2	(0		0
_	Zone Pressure (psi): Zone Pressure (psi):		52 27		47 25		47 25		49.3 26.6	2	6		25.7 25.2		25.3 25
	/ell Field Flow (MGD):						12.9		12.7						
	Surge Tank Level (ft):		16 53.2		16.4 54.1		53.3		12. <i>7</i> 53.8		3.5 3.6		.3.4 52.9		18 53
	Surge Tank Level (ft):		92.4		90.4		79		89.3		5.6		34.8		35
	Flow (16" Line):		92.4 NR		NR		NR		8.5	43			0		0
	Pressure (psi)		NR		NR		NR		NR		R		NR		24.9
	PS Pressure (psi)		NR		NR		52		53		0		27.8		28.4
Well No.	Flow Rate per Well		N/OFF		I/OFF		N/OFF	0	N/OFF	ON/	OFF		I/OFF		N/OFF
1	1150		OFF		OFF		OFF		OFF	o o			DFF		OFF
MR2	800		OFF	(OFF	(OFF		OFF	0	FF		ON		ON
3	1132		OFF		OFF		OFF		OFF	0			OFF		OFF
MR4	945		OFF		OFF		OFF		OFF	0			OFF		OFF
5	1071		OFF		OFF		OFF		OFF	0			ON		ON
MR6	950		OFF		OFF		OFF		OFF	0			OFF		OFF
7	1333		OFF		OFF		OFF		OFF	0			OFF		OFF
MR8	1000		OFF		OFF		OFF		OFF	0			OFF		OFF
9 MR10	882 960		OFF OFF		OFF OFF		OFF OFF		OFF OFF	0			ON OFF		ON OFF
MR11	900		OFF		OFF		OFF		OFF				OFF		OFF
12	1089		OFF		OFF		OFF		OFF				OFF		ON
MR13	1000		OFF		OFF		OFF		OFF	0			OFF		OFF
MR14	800		OFF		OFF		OFF		OFF	0			ON		ON
15	1071		OFF		OFF		OFF		OFF	0			OFF		OFF
16	1090		OFF		OFF		OFF		OFF	0			OFF		OFF
17	882		OFF		OFF	(OFF		OFF	0			ON		ON
MR18	1000		OFF		OFF		OFF		OFF		FF		OFF		OFF
19	530		OFF		OFF		OFF		OFF		FF		OFF		OFF
MR20	860		OFF		OFF		OFF		OFF		FF 		OFF		OFF
21	1200		OFF		OFF		OFF		OFF		FF 		ON		ON
MR22	1000		OFF		OFF		OFF		OFF		FF		OFF		OFF
MR23	800		OFF		OFF		OFF		OFF	0			OFF		OFF
24 25	1153 858		OFF OFF		OFF OFF		OFF OFF		OFF OFF	0	FF EE		OFF ON		OFF ON
MR26	951		OFF		OFF		OFF		OFF	0			OFF		OFF
27	664		OFF		OFF		OFF		OFF		FF		OFF		OFF
28	621		OFF		OFF		OFF		OFF	0			ON		ON
29	505		OFF		OFF		OFF		OFF		FF		OFF		OFF
30	517		OFF		OFF		OFF		OFF		FF		OFF		OFF
31*	1120		ON		ON		ON		ON	0			OFF		OFF
32	983		OFF		OFF		OFF		OFF		FF		ON		ON
33	631		OFF		OFF		OFF		OFF	0			OFF		OFF
34*	930		ON		ON		ON		ON	0	N		OFF	(OFF

	Date:	5/17/2016	5/17/2016	5/17/2016	5/17/2016	5/18/2016	5/18/2016	5/19/2016
	Time:	11:46 AM	12:50 PM	4:10 PM	5:30 PM	8:33 AM	10:07 AM	7:33 AM
Opera	ating Condtion:	Recharge and Production	Recharge and Production	Recharge and Production	Recharge and Production with the flow	Recharge and Production with the flow	Production with 13 MGD Wellfield	Production with 18 MGD Well Field
35	923	ON	ON	ON	ON	ON	OFF	OFF
36	800	OFF	OFF	OFF	OFF	OFF	OFF	OFF
37	681	ON	ON	OFF	OFF	OFF	OFF	OFF
38	697	ON	ON	OFF	OFF	ON	OFF	ON
39	937	ON	OFF	OFF	OFF	ON	OFF	OFF
40	800	ON	ON	OFF	OFF	ON	OFF	OFF
41	1153	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MR42	850	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MR43	954	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MR44	960	OFF	OFF	OFF	OFF	OFF	OFF	OFF
45**	845	OFF	OFF	OFF	OFF	OFF	OFF	OFF
46	368	OFF	OFF	OFF	OFF	OFF	ON	ON
MR47	869	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MR48	836	OFF	OFF	OFF	OFF	OFF	OFF	OFF
49	833	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MR50	883	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MR51	500	OFF	OFF	OFF	OFF	OFF	OFF	OFF
52	437	ON	ON	ON	OFF	OFF	OFF	OFF
53	555	ON	OFF	OFF	OFF	ON	OFF	OFF
54	954	OFF	ON	OFF	OFF	ON	OFF	ON
MR55	1000	OFF	OFF	OFF	OFF	OFF	OFF	OFF
56	800	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ben	tley Well No.	ON/OFF :low Rate (gpm	ON/OFF :low Rate (gpm			ON/OFF Flow Rate (gpm)	ON/OFF Flow Rate (gpm)	ON/OFF Flow Rate (gpm)
	1	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0
	2	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0
	3	OFF 0	ON 1088	ON 1076	ON 1073	ON 1082	OFF 0	OFF 0
	4	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0
	5	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0	OFF 0
	6	OFF 0	ON 992	ON 996	ON 992	ON 1008	OFF 0	OFF 0

^{*} SCADA Recorded

^{**}Flow data supplemented from Jan-Feb-Mar 2016 production well data

Company Name Reference

Address

QUOTATION

Page 2 / 6

DAB PUMPS S.p.A.
Via Marco Polo, 14 - 35035 Mestrino (PD), Italy
Tel. +39 049 5125000 - Fax +39 049 5125950
www.dabpumps.com

2013-02-22 Receiver From Hy droflo Pumps DAB Pumps Inc. Rackley, Joel 8437975002 8437976633

	Address				- 0407075000			
	Phone				8437975002			
	Fax E-mail				8437976633			
Ref.		Description			-	Q.ty	Unit pr.	Price
	Item no.	Description					omit pr.	Frice
			6 - MOTORI 6"-12"			1		
	7		firmed for this submittal.					
	\rightarrow	SIC/SIC Seal Con	firmed for this submittal.					
		TR875 55 KW DI	R			1	0.00	0.00
		8" Asynchronous	s two-poles or four-poles submersible	motor, re	ew indable			
		type, with extern	al shell made in AISI 316 stainless stee	el and su	pports in cast			
		iron with paint co	eating (standard version).					
			cation of the thrust bearing assembly a	and carbo	on bushes is			
			cture of water and glycol. Squirrel-cag				77	
				je rotor n	ibunica on			
			ring thrust bearing.	0 !	A IOI 004			
		94	lable also in full stainless steel AISI 31	6 version	1 or AISI 904		ē	
		version.		939				
		On request it's av	vailable also a version suitable for use Confirmed for this ord	with var er PE@	riable winding is			
		frequency drive	(30 Hz-60 Hz). suitable for VFD appli	cations.	J			
		The motor is equ	ipped with 5 meters three-core flat cal	ble direct	ly connected			
		w ith the w inding	s and it's					
		available w ith(DC	DL)pr -STAR-DELTA- starting type.					
		The cable is cert	fied ACS and WRAS. Overload protec	tion mus	t be provided			
		by user.	•		•			
			0 and PTC temperature sensors. -Stan	dard ver	sion with			
		PVC w inding.	o una i lo tomporataro comocio. Stam	uai u 10ii				
			uest a PE2+PA w inding version for inv	ortor opr	lication			
		Flanging to NEMA Protection rating Maximum w orkin	IP 58 (IP 68 on request)					
		Motor construction	on characteristics					
		STATOR. The re	w indable stator is protected by an AIS	316 sta	inless steel			
			on request). In the standard version th					
			offering superior dielectric properties					
			coolant. On request, we can supply a					
		TO THE SHARE CHIEF CONTROL OF THE STATE OF T	that makes the motor compatible with					
			of a variable frequency drive. The mo					
		december of	oltages and frequencies.	noi cairi	be supplied for			
		different input vo	ntages and frequencies.					
		DOMED OADIE	A II	:4h - F	2			
			All motors are supplied as standard w					
		1.00	nnected directly to the winding. ACS a	na vvras	s certified			
		cable. Motor ava	ilable in OOL and Serversion.					
		0						
			upper and low er supports are made of					
			n) and equipped with carbon-graphite					
		20.00	ates the EPDM membrane designed to	compen	sate for			
		motor internal pr						
		Available in AISI	316 or 904 stainless steel on request.	_				
Projec	1		Project ID	Cro	ated by		Created on	Last update
, rojet			Tesla Motor Submittal	Cie	atou by		2013-02-22	Last apaate
			Issia motor submittal				2010-02-22	

2013-02-22

QUOTATION

DAB PUMPS S.p.A. Via Marco Polo, 14 - 35035 Mestrino (PD), Italy Tel. +39 049 5125000 - Fax +39 049 5125950 www.dabpumps.com

Page 3 / 6 Receiver From Company Name Reference Hydroflo Pumps DAB Pumps Inc. Rackley, Joel Address Phone Fax 8437975002 8437976633

	Fax E-mail			8437976633	3			
Ref.	Item no.	Description	1			Q.ty	Unit pr.	Price
		THRUST BEA	ARINGS SYSTEM.				n 2	
		Mitchell type	thrust bearings with la	apped pads in graphite s	teel and ceramic			
		clearance rir	ng.					
		from 30 hp to	o 150 hp 60000 N					
			ust load 12500N					
		ROTOR SHA	FT Rotor shaft in stain	less steel. The rotor is n	nade of copper			
		for all sizes			The state of the s			
		MECHA NICA	L SEAL In the standard	d version the motor is ed	uipped with a			
		-ceramic/cark	bon mechanical seal. C	n request we can supp	ly a silicon			
			hanical seal (SiC/SiC)	and the second s				
			,					
	60144583	Motor: TR8	75 55 KW DIR			1	On req.	On req
		Subtotal:					On req.	On req
						-		
		SERIES MO	TORS - MOTORI 6"-12	!"		1		
		TR8100 75 H	KW DIR			1	0.00	0.0
		8" Asynchro	onous two-poles or fou	ır-poles submersible mo	tor, rew indable			
		type, with ex	xternal shell made in A	ISI 316 stainless steel a	nd supports in cast			
		iron with pai	int coating (standard ve	ersion).				
		Cooling and	lubrication of the thrus	t bearing assembly and	carbon bushes is			
		provided by	a mixture of water and	d glycol. Squirrel-cage re	otor mounted on			
		Mitchell self-	-centring thrust bearing	J.				
		The motor is	available also in full st	ainless steel AISI 316 v	ersion or AISI 904			
		version.						
	\longrightarrow	On request	it's available also a ver	sion suitable for use wi	th variable			
		frequency d	drive (30 Hz-60 Hz).	Confirmed for this order	PE@ winding is suit	able for	VFD application	S.
		The motor is		rs three-core flat cable				
		w ith the w in	ndings and it's					
		available w i	ith(DOL) or -STAR-DELT/	≒starting type.				
		The cable is	certified ACS and WR	AS. Overload protection	must be provided			
		by user.						
		On request	PT100 and PTC temper	ature sensors. Standar	d version with-			
		-PVC w inding	g . 					
	\rightarrow	Available on	n request a PE2+PA wir	nding version for inverte	er application.			
		Flanging to I	NEMA 8"					
		Protection ra	ating IP58 (IP68 on red	quest)				
		Maximum w	orking depth: 300 m.					
		Motor const	truction characteristics					
		STATOR TH	he rew indable stator is	protected by an AISI 31	6 stainless steel			
		jacket (AISI	904 on request). In the	standard version the re	otor is wound with			
	I .							
		-I- VC coated	I w ire offering superior	dielectric properties tric	at allow direct	- 1		
				est, we can supply a ve				
Projec	-						Created on	Last update

DAB

Company Name Reference

Address

QUOTATION

Page 4 / 6

DAB PUMPS S.p.A.
Via Marco Polo, 14 - 35035 Mestrino (PD), Italy
Tel. +39 049 5125000 - Fax +39 049 5125950
www.dabpumps.com

2013-02-22

 Receiver
 From

 Hy droflo Pumps
 DAB Pumps Inc. Rackley, Joel -8437975002 8437976633

	Address Phone Fax E-mail		*			8437975002 8437976633			
ef.	Item no.	Description	on				Q.ty	Unit pr.	Price
	\rightarrow	PE2+PA w	inding that make	es the motor com	patible w ith spec	ial applications			
		and with th	ne use of a varia	able frequency d	rive. The motor of	an be supplied fo	or		
		different in	put voltages an	d frequencies.					
		POWER CA	ABLE All motors	s are supplied as	standard w ith a	5 m 3-core			
		pow er cab	le connected di	irectly to the wind	ding. ACS and W	RAS certified			
		cable. Moto	or available in (D	OL) and SD versi	on.				
		SUPPORTS	S. The upper an	d low er supports	are made of pa	nted cast iron			
		(standard	version) and eq	uipped with carb	on-graphite bus	nings. The lower			
		support ind	corporates the E	⊋DM membrane	designed to com	pensate for			
			nal pressure.						
		Available ii	1 AISI 316 or 9 0	4 stainless steel	on request.			3	
			EARINGS SYST						
				gs with lapped pa	ads in graphite s	eel and ceramic			
		clearance							
			to 150 hp 6000				5		
		Counter-th	rust load 12500)N					
		THE PARTY OF THE P		ft in stainless ste	el. The rotor is n	ade of copper			
		for all size	S						
		MECHANIC	AL SEAL In the	standard versio	n the motor is eq	uipped with a			
		-ceramic/ca	arbon mechanic	al seal. On reque	stwe can supp	y a silicon			
	\rightarrow	⊧carbide me	echanical seal (SiC/SiC)	ž				
	60144585	Motor: TF	R8100 75 KW DI	IR			1	On req.	On re
		Subtotal:						On req.	On red

Total price excl. VAT	VAT in %		Total price incl. VAT	
		20		
Project	Project ID Tesla Motor Submittal	Created by	Created on 2013-02-22	Last update



DATA SHEET

2013-02-22

Page 5 / 6

DAB PUMPS S.p.A.
Via Marco Polo, 14 - 35035 Mestrino (PD), Italy
Tel. +39 049 5125000 - Fax +39 049 5125950
www.dabpumps.com

Company Name

ne Hydroflo Pumps

From DAB Pumps Inc.

Reference Address Phone Fax Rackley, Joel -8437975002 8437976633

Motor:

E-mail

TR875 55 KW DIR

Motor Code :

60144583

Materials

Shaft

Stainless steel

Shaft end

Stainless Steel AISI 316

Mechanical seal

-Carbon/Geramic- Silicone Carbide (SiC)

Bush

Graphite

Cable

EPDM

Structural parts

Cast iron

Pump liner

Stainless Steel AISI 316

Washer

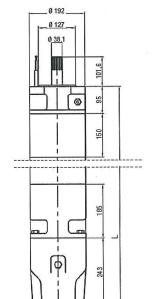
Ceramic

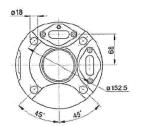
Thrust bearing

Graphite EPDM

Diaphragm Screws

Stainless Steel AISI 304





Motor data

Motor brand:

TESLA

Nominal power P2:

73.756 hp

Rated speed:

3500 rpm

Rated voltage:

3~ 460 V 60 Hz

Nominal current :

109 A

Degree of protection:

IP 58

Weight:		423.28 lb							
Dimensio	ns in	inch							
L	53.15								



DATA SHEET

Page 6 / 6 2013-02-22

DAB PUMPS S.p.A. Via Marco Polo, 14 - 35035 Mestrino (PD), Italy Tel. +39 049 5125000 - Fax +39 049 5125950 www.dabpumps.com

Company Name

Reference Address Phone E-mail

Hy droflo Pumps

Receiver

DAB Pumps Inc. Rackley, Joel

8437975002 8437976633

Motor:

TR8100 75 KW DIR

Motor Code:

60144585

Materials

Shaft

Stainless steel

Shaft end

Stainless Steel AISI 316

Mechanical seal

Carbon/Ceramie Silicone Carbide (SiC)

Bush

Graphite

Cable

EPDM

Structural parts

Cast iron

Pump liner

Stainless Steel AISI 316

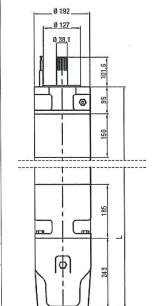
Washer Thrust bearing Ceramic Graphite

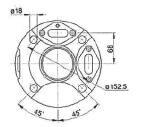
Diaphragm

EPDM

Screws

Stainless Steel AISI 304





Motor data

Motor brand:

TESLA

Nominal power P2:

100.58 hp

Rated speed:

3500 rpm

Rated voltage: Nominal current :

145 A

3~ 460 V 60 Hz

Degree of protection:

IP 58

Weight:	:	522.49 lb	
Dimens	ions in	inch	
L	62.598		

Company: HYDROFLO PUMPS USA, INC.

Name:

Date: 2/15/2013



Pump:

Size: 9HL (2 stage)

Type: Submersible

Synch speed: 3600 rpm

Curve: 9HL Specific Speeds:

Dimensions:

Dimensions:

Vertical Turbine:

Speed: 3510 rpm Dia: 6.4 in

Impeller: 9HL SS ENCL

Ns: ---Nss: ---

Suction: 6 in Discharge: 8 in

Bowl size: 9.25 in Max lateral: 0.75 in Thrust K factor: 9 lb/ft

Pump Limits:

Temperature: 140 °F Pressure: 420 psi g Sphere size: 0.25 in Power: 300 hp Eye area: 16.9 in² Search Criteria:

Flow: 1200 US gpm

Head: 250 ft

Temperature: 68 °F

Fluid:

Water

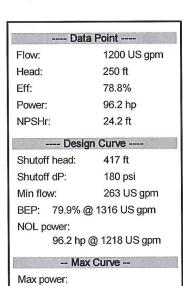
Density: 62.32 lb/ft³ Viscosity: 0.9946 cP Vapor pressure: 0.3391 psi a Atm pressure: 14.7 psi a

NPSHa: ---

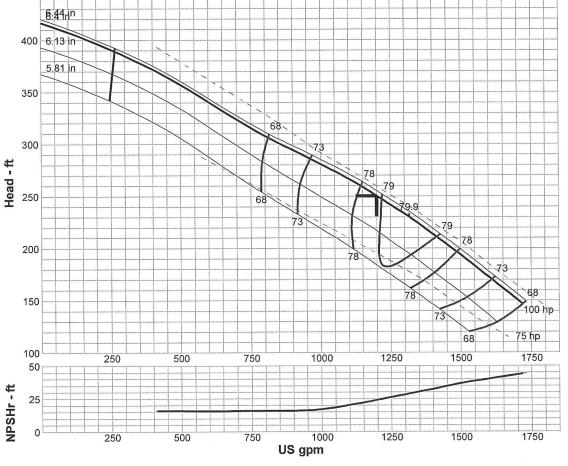
Motor:

Standard: NEMA Enclosure: TEFC Size: 100 hp Speed: 3600 Frame: 405TS

Sizing criteria: Max Power on Design Curve



98.2 hp @ 1219 US gpm



aluation:				
Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
3510	206	78.6	95.1	34.2
3510	250	78.8	96.2	24.2
3510	286	72.9	95.2	16.4
3510	321	62	92.3	16
3510	359	46.2	92.4	16
	Speed rpm 3510 3510 3510 3510	Speed Head rpm ft 3510 206 3510 250 3510 286 3510 321	Speed rpm Head ft Efficiency % 3510 206 78.6 3510 250 78.8 3510 286 72.9 3510 321 62	Speed rpm Head ft Efficiency % Power hp 3510 206 78.6 95.1 3510 250 78.8 96.2 3510 286 72.9 95.2 3510 321 62 92.3

Company: HYDROFLO PUMPS USA, INC.

Name:

Date: 2/15/2013



Pump:

Size: 9HL (2 stage)

Type: Submersible

Synch speed: 3600 rpm

Curve: 9HL

Dia: 5.81 in Impeller: 9HL SS ENCL

Specific Speeds:

Ns: ---Nss: ---

Dimensions:

Suction: 6 in Discharge: 8 in

Speed: 3510 rpm

Vertical Turbine:

Bowl size: 9.25 in Max lateral: 0.75 in Thrust K factor: 9 lb/ft

Pump Limits:

Temperature: 140 °F Pressure: 420 psi g

Sphere size: 0.25 in

Power: 300 hp Eye area: 16.9 in² Search Criteria:

Flow: 1200 US gpm

Head: 182 ft

Fluid:

Water

Density: 62.32 lb/ft3

Viscosity: 0.9946 cP

NPSHa: ---

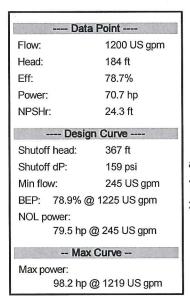
Temperature: 68 °F

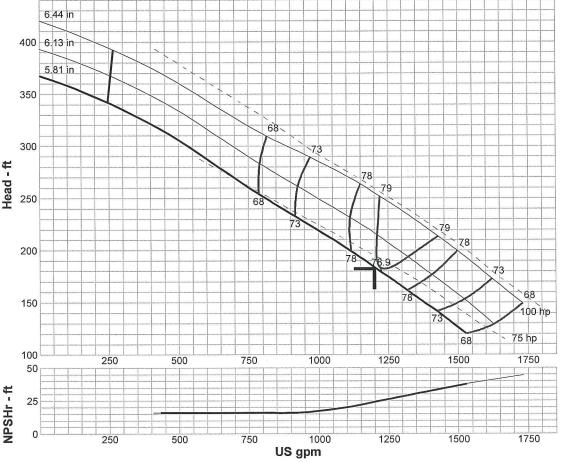
Vapor pressure: 0.3391 psi a Atm pressure: 14.7 psi a

Motor:

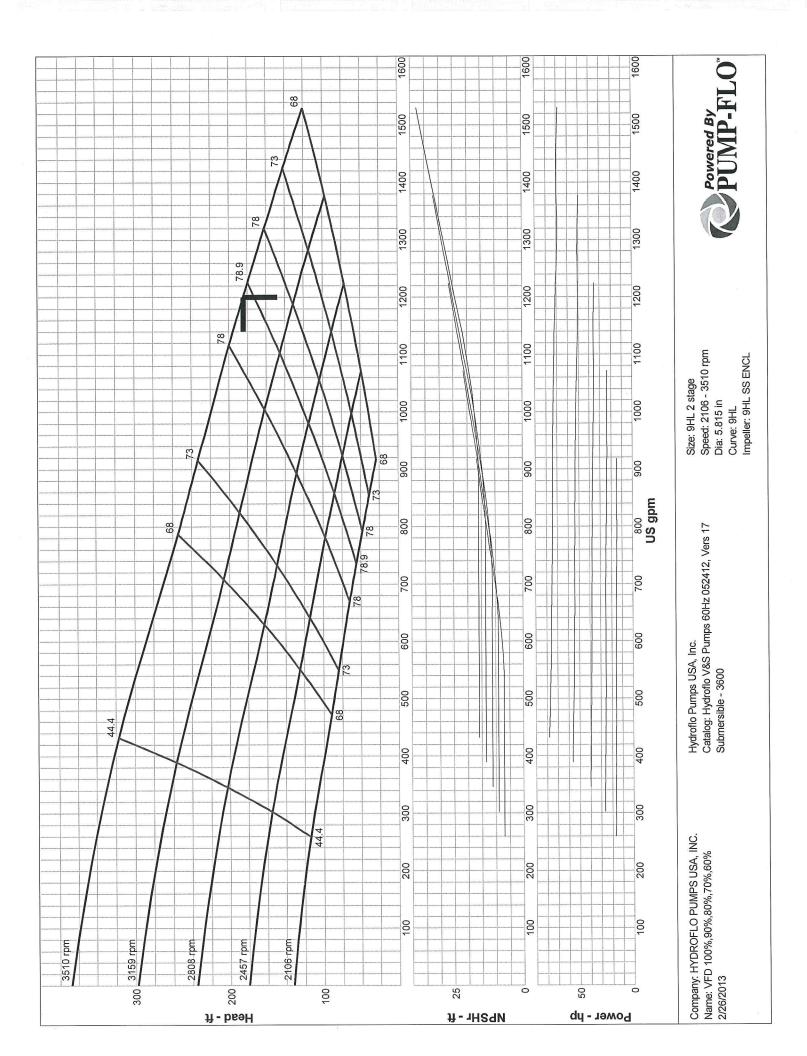
Standard: NEMA Enclosure: TEFC Size: 100 hp Speed: 3600 Frame: 405TS

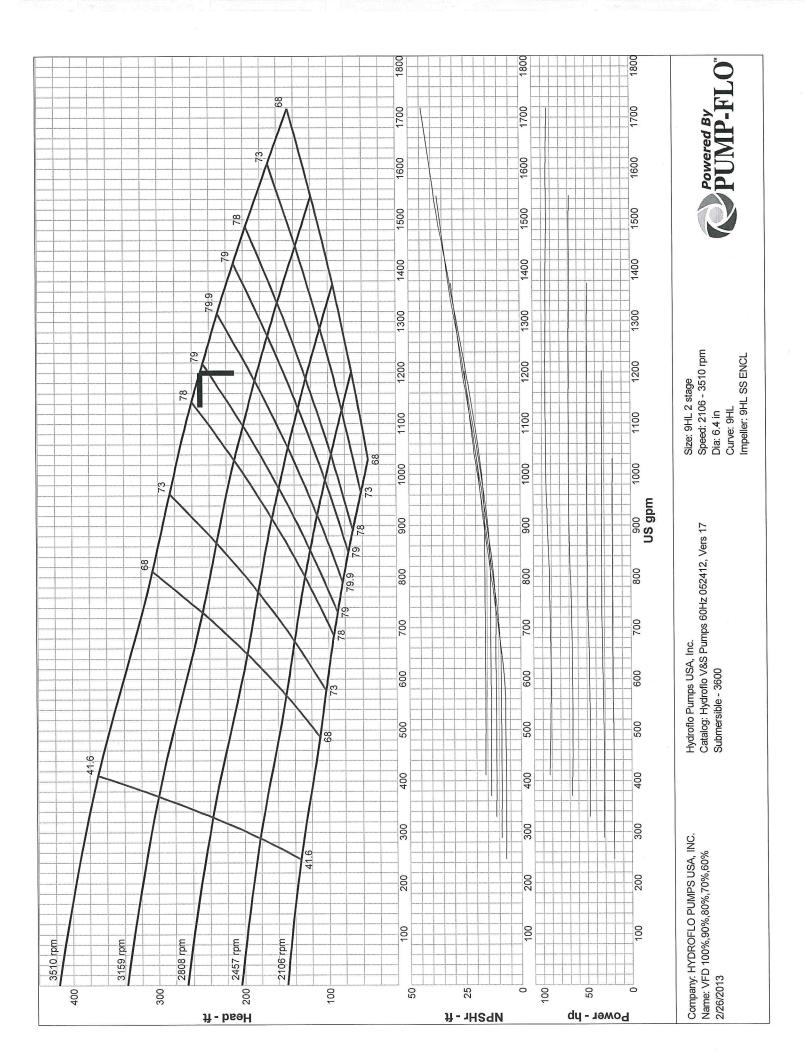
Sizing criteria: Max Power on Design Curve





Performance Evaluation:										
Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft						
3510	138	72.2	69.5	34.2						
3510	184	78.7	70.7	24.3						
3510	225	74.1	73.4	17.1						
3510	266	63.6	74.9	16						
3510	308	47.6	77.2	16						
	Speed rpm 3510 3510 3510 3510	Speed Head rpm ft 3510 138 3510 184 3510 225 3510 266	Speed rpm Head ft Efficiency % 3510 138 72.2 3510 184 78.7 3510 225 74.1 3510 266 63.6	Speed rpm Head ft Efficiency % Power hp 3510 138 72.2 69.5 3510 184 78.7 70.7 3510 225 74.1 73.4 3510 266 63.6 74.9						







SYM. REVISION DATE

ΒY

RM

-STOP RING

10-2-09

Effective OCTOBER 2, 2009

DIA.

Submersible Turbine Pumps Engineering Data

Size: 9H **9M**

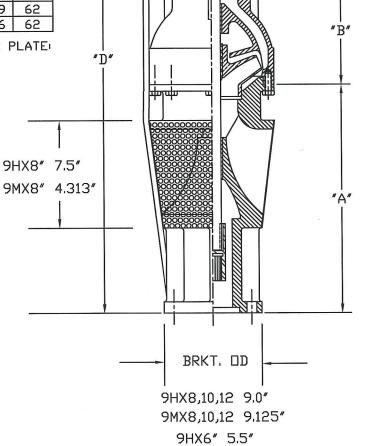


Model	NEMA	"A"	"B"	"C"	"D" SINGLE STAGE	"E"	Disch. Size	First Stage Wt.	Add'l Stage Wt.
9H	6	15.75	9.31	4.50	29.63	9.44	6,8	167	69
	8,10,12	20.00	9.31	4.50	33.81	9.44	6,8	194	69

Model	NEMA	"A"	"B"	"C"	"D" SINGLE STAGE	"E"	Disch. Size	First Stage Wt.	Add'l Stage Wt.
9М	6	17.0	8.47	4.50	29.97	9.44	6,8	159	62
	8,10,12	15.75	8.47	4.50	28.72	9.44	6,8	186	62

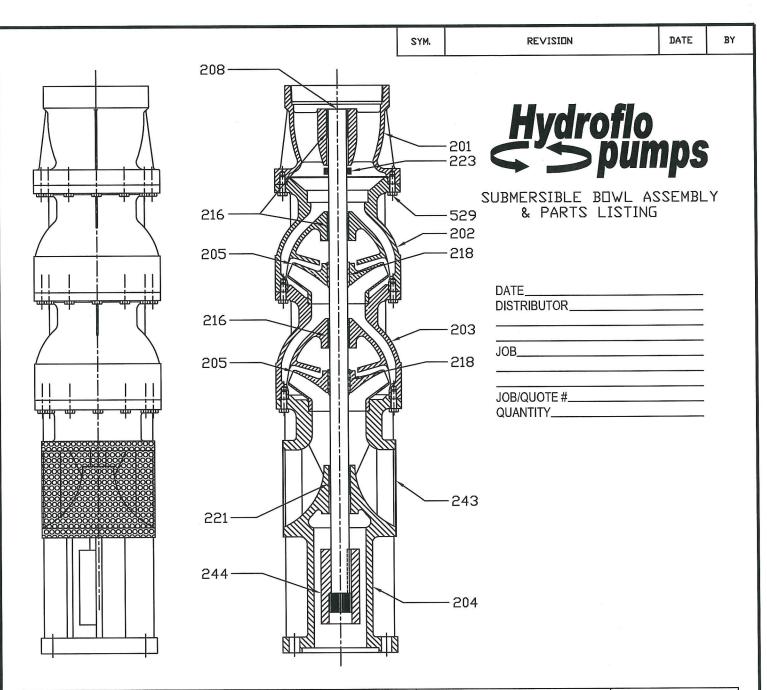
NDTE: 9M WITH 6" MTR. BRKT IS WITH AN ADAPTER PLATE:

SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE (All dimensions are in inches and weights in lbs.)



9MX6" 9.0"

A-00216 REV.



CATALOG NUMBER	QTY.	PART NAME	STANDARD MATERIAL (A.S.T.M. DESIGNATION)	SPECIFICATION REQUIREMENT
201	1	DISCHARGE CASE, DUCTILE IRON	A-536 GR. 65-45-12	
202	1	BOWL, TOP HOUSING	CAST IRON A-48 CLS 30	~
203		BOWL, INTERMEDIATE HOUSING	CAST IRON A-48 CLS 30	
204	1	SUCTION CASE/MTR. BRKT., DUCTILE IRON	A-536 GR, 65-45-12	
205		IMPELLER	SS GR, 304	
208	1	SHAFT, BOWL	SS GR. 416	
216		BEARING, DISCH. & BOWL	BRONZE B-505-932	
218		COLLET, IMPELLER	SS GR. 416	
221	1	BEARING, SUCTION CASE/MTR. BRKT.	BRONZE B-505-932	
223	1	RING, LATERAL STOP	416 STAINLESS STEEL	
243	1	SCREEN	316 STAINLESS STEEL	
244	1	MOTOR COUPLING	416 STAINLESS STEEL	
245		GUARD, WIRE (OPTIONAL) NOT SHOWN		
529		SCREW, CAP	18-8 STAINLESS STEEL	

Manufacturing Quality Pump Products

Vertical Turbine Pumps

Ductile Iron Discharge Heads

Submersible Turbine Pumps

Propeller & Mixed Flow Pumps

Dewatering & Sewage Pumps

Air Pumps & Diffusers

Close Coupled Centrifugals

Stainless Multi-stage Boosters

Floating Pumps & Fountains

Self Primer Pond & Pool Pumps

Fountain Nozzles & Spray Heads

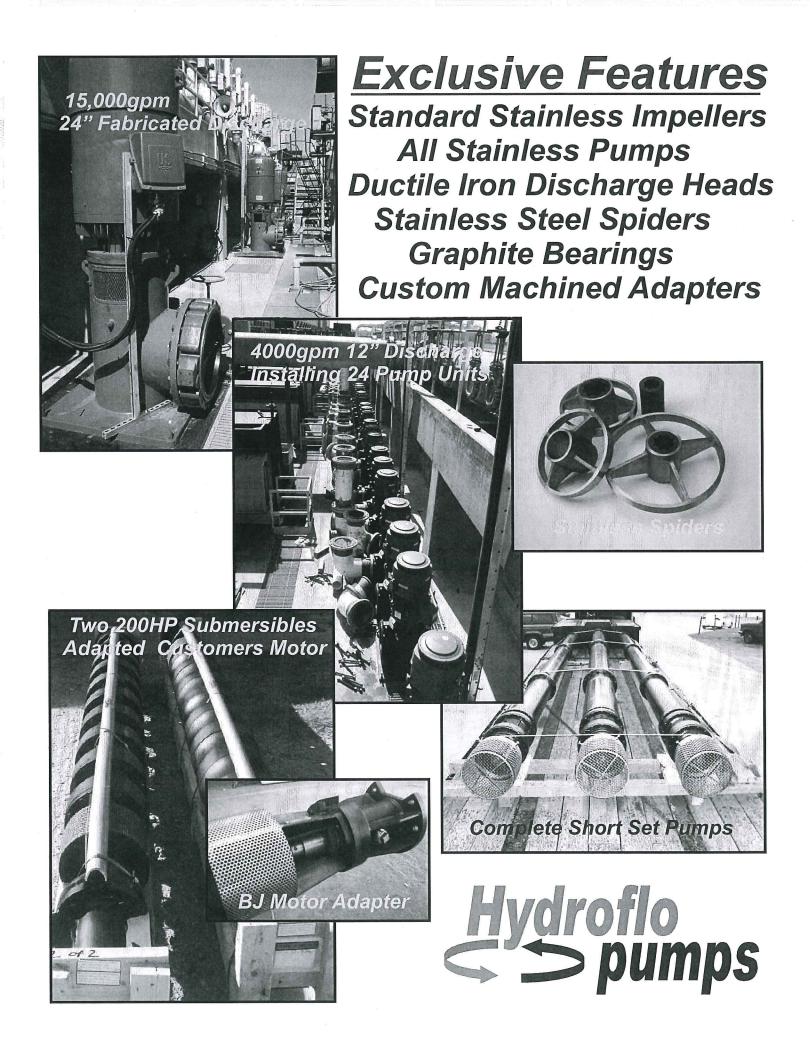
LED Submersible Lighting

Custom Control Centers

Investment Cast Stainless Impellers 60gpm to 6000gpm

Hydroflo Spumps

www.hydroflopumps.com



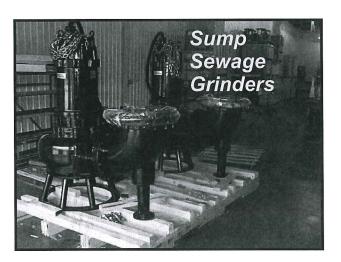


Fire Protection for off shore oil platforms

Hydroflo Pumps has 316SS and 304SS pump parts in stock to build the pumps needed to protect oil company drill platforms. These are the same products used in other salt water applications and high saline water wells. Distributors and Contractors look to Hydroflo for quick delivery of these specialty pumps.

Nuclear Plant cooling tower pumps

Hydroflo Pumps has provided over 140,000 gpm of cooling capacity to one of the largest Nuclear Plants in the USA. With individual pump capacities over 30,000 gallons per minute, Hydroflo has provided many industrial and municipal cooling tower projects. Steel mills to classrooms, our engineers have met the pumping requirements.



Chicago and Detroit chose Hydroflo Pumps

Hydroflo has engineered and sold pumps to both large and small cities. We have worked with the Corp of Engineers, Department of Natural Resources, and many city governments to provide specified pump projects. Hydroflo has designed and delivered sewage pumps, stormwater pumps and potable water pumps for all their engineered applications.

Standard Stainless Impellers

Hydroflo provides investment cast stainless steel impellers in all our vertical and submersible turbines to 6000 gpm. The stainless provides all customers with better abrasive and chlorine resistance in their pumps. Hydroflo builds better pumps for better service.

Hydroflo Pumps USA, Inc.



Engineering Facts

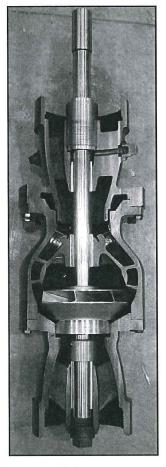


www.hydroflopumps.com



Abrasive Duty Mechanical Seal

- Balanced Multi-Spring
- Tungsten-Carbide Faces
- 316SS with Viton Elastimers



Cutaway

Extending Vertical Turbine Life:

□igh Chlorine Content □ □pgrade shaft material to □□□□□ or □□□□□ and up□

Clear, Potable Water is EASY!

curve is exponential; double the speed, four times the wear.

When pumping abrasive water, also consider lowering pump speed. The wear

We can handle it ALL with Stainless Impellers.

Hydroflo Turbines

Job Specific:

- 1. Offshore Fire Pumps
- 2. Steel Mill Cooling
- 3. Mine Dewatering
- 4. Swimming Pool
- 5. Brackish Boosters
- 6. RO Treated Water
- 7. Abrasive Raw Water
- 8. Propane & Butane



Pouring Investment Stainless Steel Castings

□ droflo Pumps □ A□nc. □□□□ □ obloll□ Pine □ l□d. Fair □ ew □ T□. □□□□2

Engineering Facts



www.hydroflopumps.com



More Stainless Products:

- Stainless steel bearing retainers.
- Stainless steel packing boxes.
- Stainless steel column couplings.
- · Stainless steel shaft sleeves.
- Complete Stainless Steel Pumps.



☐ffshore Fire Pumps

Lost Wax Investment Cast Stainless Steel Impellers

- 1. Lost wax investment castings are superior to all other impeller castings.
 - A. The smoothness of the casting increases efficiencies.
 - B. The wax is injected into a stainless pattern, thus a perfect mold each injection.
 - C. Sand castings will have core shifts, increased void areas, and rough surfaces.
- 2. Stainless is superior to bronze in all engineering applications.
 - A. Strength and Hardness are considered two of the most important physical properties when choosing pump impeller material. Stainless impellers have a Brinell Hardness Range of 212—280, the best choices in bronze are 60—159. Tensile Strength for stainless is 80,000—135,000 PSI, again bronze is only 26,000—85,000 PSI.
 - B. Stainless steel is better against abrasion and corrosion. Stainless is the choice in high chlorine concentrations, salt water applications, and in low PH water.
 - C. Stainless should always be chosen for applications where the presence of sand or abrasion particles are known to be in the water.

201 Stainless

201SS Brinell 215—280

304SS Brinell 212—277

316SS Brinell 150—190

316SS is the better material against corrosion, but 201SS is best in abrasive applications.



Hydroflo Pumps USA, Inc.
7118 Loblolly Pine Blvd. Fairview, TN. 37062
Phone: (615) 799-9662 Fax: (615) 799-5654

Engineering Facts

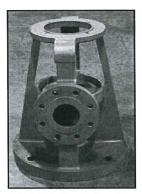


www.hydroflopumps.com



More Ductile Iron Products:

- ubmersibles are all Ductile ion castings.
- □droflo has pump models a aliable in Ductile Ion Double Tapped and □□ □inged for □igh Pressure Applications.
- 🔼 Ductile Ifon Dearing Detainers.
- Ductile Inon Tube Adapters

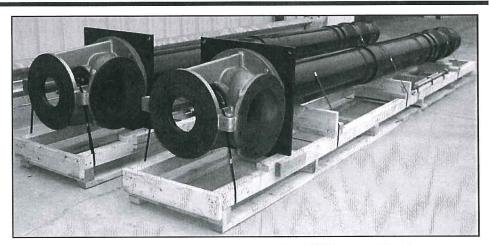


ANSI 300 lb. 4" Ductile Iron Discharge Head

□ droflo Pumps □□A □ nc.
□□□□□ obloll□ Pine □ l cd.
Fair □ ew □ T□. □□□□ 2

Ductile Iron Discharge Heads With Identical Centerlines

- □ Ductile ☐on is a superior casting material o☐er Class ☐☐☐Cast ☐on.
- □ ecause of this strength □□ □droflo Ductile □on discharge heads can handle higher pressures and more hang weight.
- ☐ The porosit☐in Ductile ②fon is much smaller☐thus pro☐ding a better corrosi☐e resistance than Cast ③fon.
- ☐ Cast ☐on is a brittle casting. Ductile ☐on has a stretch factor and will not brea☐or crac☐as eas☐as Cast ☐on.
- □ □droflo pro □des □□□□□□□and □□□Ductile ாon discharge heads with identical centerlines. This allows different si □ pumps to connect into the same height header pipe.



Hydroflo assembled short set pumps with 12" Discharge Heads.



"Realize the Power of Stainless"

The New Leader in Vertical and Submersible Turbine Pump Engineering



- 1. Lost Wax Investment Cast Stainless has the Highest Efficiency
- 2. Stainless impellers are THREE times harder than bronze
- 3. Stainless will wear longer in abrasive applications
- 4. Stainless is resistant to Salt Water and Chlorine
- 5. Stainless is LEAD FREE

"Why would you specify anything less?"

"Great People, Great Products, Great Service"

www.hydroflopumps.com

Hydroflo Pumps USA, Inc. 7118 Loblolly Pine Blvd. Fairview, TN., 37062

Engineering Facts



www.hydroflopumps.com



"Zero Lead" Stainless Steel Spiders



□i□ube

Vesconite □earings

□onger □ife

□etter Abrasi □e Wear

□ow Friction



All 316SS

Construction

Available

Hydroflo Pumps Introduces Standard "Zero Lead" Pumps

□ ew state laws ha e been implemented to restrict the amount of lead in a component of a drin ing water s stem to . □□2□□ .

(1/4 of 1 percent)

- 2. □ droflo Pumps is offering standard □□E□□□ □EAD□pumps. □tainless steel impellers □Vesconite bearings □cast iron lined bowls and stainless steel hardware.
- □ □ther pump manufacturers are offering □ow lead □options.
- □ Who assumes the LIABILITY?

THE INSTALLER!

You are Safe with "ZERO"

Impeller Options

201 Stainless

304 Stainless

316 Stainless



Hydroflo Pumps USA, Inc.

7118 Loblolly Pine Blvd. Fairview, TN. 37062

Phone: (615) 799-9662 Fax: (615) 799-5654



Engineering Facts

www.hydroflopumps.com-



Lead & Zinc Free

Longer Wearing

Composite Bearings

Available & "In Stock"



Lead & Zinc Free Stainless Steel Bearing Retainers



Swimming Pools
Water Parks
Booster Pumps

Chlorine Destroys Bronze Impellers & Wear Rings By Dezincification

Dezincification is the process of selective removal of zinc from copper-zinc alloys. This leaves your bronze impeller or wear ring a porous mass of copper with very little strength.

Drinking water and swimming pools are usually treated with dilute solutions of a few parts per million (ppm) of chlorine. The AWWA permits 25ppm for 24 hours in case of emergency disinfection. Stainless steels are resistant to the chlorine for this relatively short, high concentration exposure and can cope with continuous exposure of 2ppm chlorine at ambient temperature and neutral pH.



Stainless Steel Impellers vs Bronze Impellers

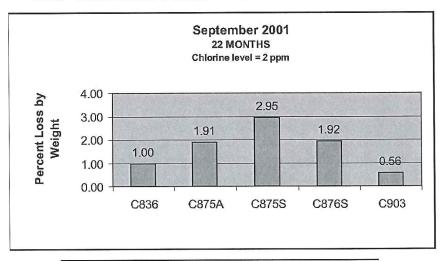
The below chart, from Sterling Fluid Systems, Inc., shows the impeller weight loss from running different **BRONZE** impellers in a 2 ppm Chlorine solution. They also noted that more product loss was evident with higher concentrations of chlorine.

C836—SAE40 Bronze 5% Zinc

C875A—Silicon Bronze 16% Zinc

C875S—Silicon Bronze 12% Zinc

C903—Tin Bronze 4% Zinc



□ droflo Pumps □□A□nc. □□□□ □ bloll□ Pine □ □d. Fair □ ew □ T□. □□□□2

Engineering Facts



www.hydroflopumps.com



Abrasive Duty Mechanical Seal

- Balanced Multi-Spring
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- 316SS with Viton Elastimers



Our Standard

Hydroflo is the Leader

In Stainless Steel Turbine

Products

<u>Hydroflo Turbines</u> Job Specific:

- 1. Offshore Fire Pumps
- 2. Steel Mill Cooling
- 3. Mine Dewatering
- 4. Nuclear Power Plants
- 5. Saltwater Supply
- 6. RO Treated Water
- 7. Abrasive Raw Water
- 8. Propane & Butane

MINING

Submersible Turbine Pumps and Vertical Turbine Pumps

- Standard m̄ estment Cast □tainless □teel m̄pellers□ 2 □ 2 times harder than the competitions bron □ impellers. □ o efficienc □ or performance loss □ our patterns are engineered for stainless steel.
- 2. **Standard** □□□□P□ high chrome shafting □onger life and a □□ □oc well C.
- □ Standard Vesconite □i□ube Abrasi□e □esistant □earings□ □times the life of bron□e bearings in abrasi□e applications. A□ailable □i Temp bearings□for applications o□er □□□ degrees F.
- □ Standard Ductile Iron Discharge □eads with □ertical turbines □higher pressure and more corrosi □e resistant than the competitions cast iron.
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- ☐ Available all stainless steel construction ☐ again ☐ with no loss in performance.

Best Pump Performance Available with Stainless Steel Impellers



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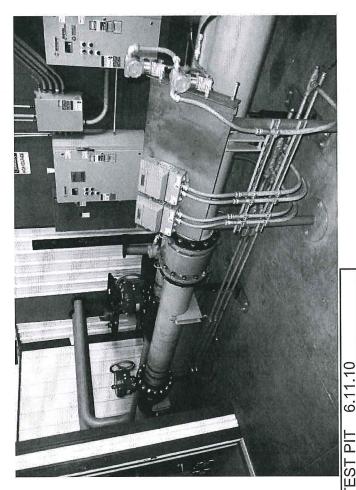
Peru Copper Mines

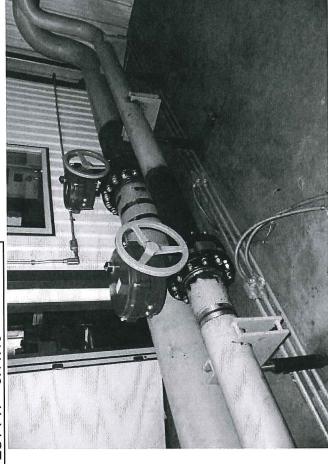
Panama □old Mines

Dewatering □urface Mines

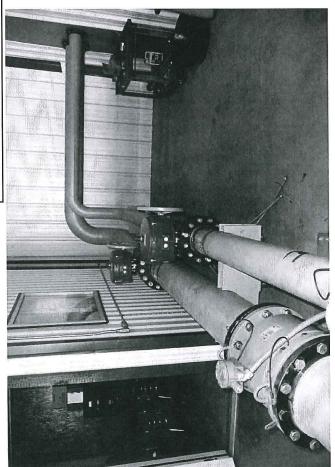
Pouring Investment Stainless Steel Castings

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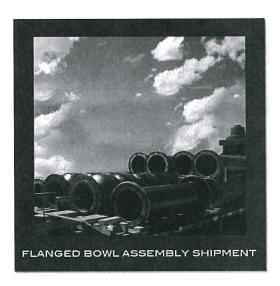
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HARDNESS OF MATERIALS

Hardness is one of the physical properties generally considered to be an important factor in selection of the best material for given service. Numerous methods have been developed to describe the degree of hardness of a material. Brinell, Rockwell, Vickers and Shore are the most widely used scales and can be compared by use of conversion tables. As you will note, various scales must be used with the Brinell and Rockwell methods in order to cover the full range of hardness. A hard material (high hardness number) is likely to have a high tensile strength and be somewhat brittle. The tensile strength of steel can be roughly approximated by multiplying the Brinell hardness by 500.

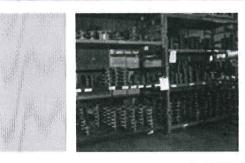
The approximate range of Brinell hardness for a number of the metals commonly used in the Hydroflo Pumps vertical turbine industry are listed below:

Metal	Tensile Strength (PSI)	Brinell Hardness Range
Cast Iron	30000	190-210
	40000	210-250
	50000	230-280
410-416 Stainless Steel	75000-135000	155-290
Ductile Iron	60000	132
1045 Steel	80000-120000	160-240
316 Stainless Steel	80000-90000	150-190
304 Stainless Steel	85000-125000	212-277
201 Stainless Steel	105000-135000	215-280
Monel 400	84000-120000	160-225
K Monel	135000-185000	255-370
17-4 PH Stainless Steel	145000-200000	311-420
Aluminum Bronze	80000-110000	150-250
SAE 40 Bronze	26000-42000	60-80
Nickel Aluminum Bronze	85000	159

The hardness and tensile strength of many materials can be changed considerably by heat-treating or cold-working. An example of the latter is cold-drawn shafting which has harder and stronger metal near the surface of the shaft than in the center.

It is difficult to obtain accurate hardness measurements of thin sections of materials such as coatings and overlays applied over a softer material. The actual hardness is not of great importance in this instance as the wear characteristics of a material are more likely to be related to its "toughness" or the mating surface than to the hardness. This is not to say that materials with low hardness ratings have excellent wear resistance.





















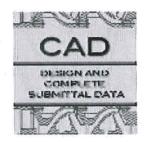








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Motor Reference Listing

1) HD Fowler Inc.

13440 S.E. 30th Street Bellevue, WA 98005

Phone Numbers Voice (425) 746-8400 Fax (425) 641-8885

Contact: Rich Walz

2) Larsen Farms

2650 N. 2375 E. Hamer, ID 83425

3) Coast Pump Water Technologies

610 Groveland Ave Venice, FL 34285 (941) 484-3738

Contact: Danny Ahrens

4) Alstra Industries

9229 S Hardy Dr. Tempe, AZ 85284 (480) 496-6300

Contact: Randy Peterson



Declaration of conformity

We

TESLA S.r.l.Via del Lavoro n° 3 – San Germano dei Berici (VI) Italy

declare under our responsibility that the products

- TR8 series submersible motors

to which this declaration relates are in conformity with the following directives:

- 2006/95/CE (Low Voltage Directive)
- 2004/108/CE (Electromagnetic Compatibility Directive)
- 2006/42/CE (Machine Directive)

by the following standards:

- EN 60034-1:2010

by the following

-NEMA MG 1-2007 (Paragraph 1 part 31 / 18.171-18.181)

San Germano dei Berici (VI) lì 2012-02-21

Tesla S.r.l.

Giuliano Moretto (R&D Manager)

Galante St

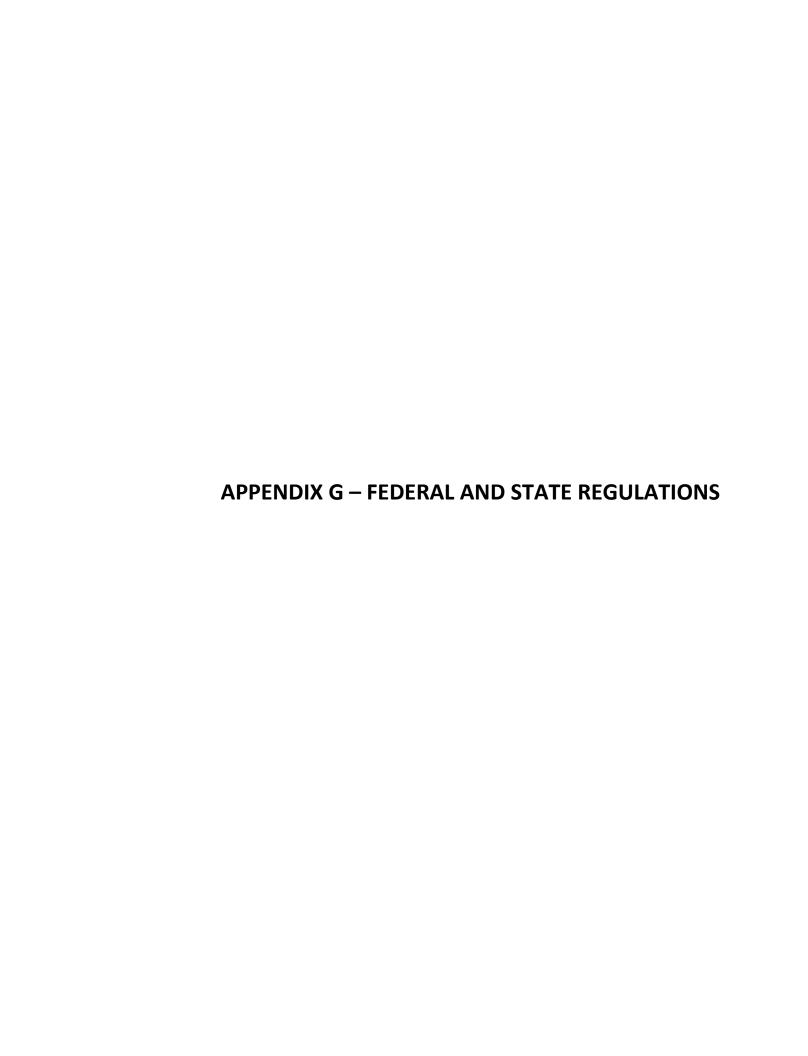


Table G.1 Maximum Contaminant Levels for Drinking Water Contaminants

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
Microorganisms		
Cryptosporidium	0	TT ¹
Giardia lamblia	0	TT ¹
Heterotrophic plate count		TT ¹
Legionella	0	TT ¹
Total Coliforms	0	5.0%2
Turbidity		TT¹
Viruses (enteric)	0	TT ¹
Disinfection Byproducts		
Bromate	0	0.01
Chlorite	0.8	1.0
Haloacetic acids (HAA5)		0.060
Total Trihalomethanes (TTHMs)		0.080
Disinfectants		
Chloramines (as Cl ₂)	4	4
Chlorine (as Cl ₂)	4	4
Chlorine dioxide (as ClO ₂)	0.8	0.8
Inorganic Chemicals		
Antimony	0.006	0.006
Arsenic	0	0.01
Asbestos	7 MFL ³	7 MFL ³
Barium	2	2
Beryllium	0.004	0.004
Cadmium	0.005	0.005
Chromium (total)	0.1	0.1

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
Copper	1.3	TT ⁴ Action Level=1.3
Cyanide	0.2	0.2
Fluoride	4	4
Lead	0	TT ⁴ Action Level=0.015
Mercury (inorganic)	0.002	0.002
Nitrate (measured as N)	10	10
Nitrite (measured as N)	1	1
Selenium	0.05	0.05
Thallium	0.0005	0.002
Organic Chemicals		
Acrylamide	0	TT ⁵
Alachlor	0	0.002
Atrazine	0.003	0.003
Benzene	0	0.005
Benzo(a)pyrene (PAHs)	0	0.0002
Carbofuran	0.04	0.04
Carbon tetrachloride	0	0.005
Chlordane	0	0.002
Chlorobenzene	0.1	0.1
2,4-D	0.07	0.07
Dalapon	0.2	0.2
1,2-Dibromo-3-chloropropane (DBCP)	0	0.0002
o-Dichlorobenzene	0.6	0.6
p-Dichlorobenzene	0.075	0.075
1,2-Dichloroethane	0	0.005
1,1-Dichloroethylene	0.007	0.007
cis-1,2-Dichloroethylene	0.07	0.07

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
trans-1,2-Dichloroethylene	0.1	0.1
Dichloromethane	0	0.005
1,2-Dichloropropane	0	0.005
Di(2-ethylhexyl) adipate	0.4	0.4
Di(2-ethylhexyl) phthalate	0	0.006
Dinoseb	0.007	0.007
Dioxin (2,3,7,8-TCDD)	0	0.0000003
Diquat	0.02	0.02
Endothall	0.1	0.1
Endrin	0.002	0.002
Epichlorohydrin	0	TT ⁵
Ethylbenzene	0.7	0.7
Ethylene dibromide	0	0.00005
Glyphosate	0.7	0.7
Heptachlor	0	0.0004
Heptachlor epoxide	0	0.0002
Hexachlorobenzene	0	0.001
Hexachlorocyclopentadiene	0.05	0.05
Lindane	0.0002	0.0002
Methoxychlor	0.04	0.04
Oxamyl (Vydate)	0.2	0.2
Polychlorinated biphenyls (PCBs)	0	0.0005
Pentachlorophenol	0	0.001
Picloram	0.5	0.5
Simazine	0.004	0.004
Styrene	0.1	0.1
Tetrachloroethylene	0	0.005
Toluene	1	1

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)
Toxaphene	0	0.003
2,4,5-TP (Silvex)	0.05	0.05
1,2,4-Trichlorobenzene	0.07	0.07
1,1,1-Trichloroethane	0.2	0.2
1,1,2-Trichloroethane	0.003	0.005
Trichloroethylene	0	0.005
Vinyl chloride	0	0.002
Xylenes (total)	10	10
Radionuclides		
Alpha particles	0	15 pCi/L
Beta particles and photon emitters	0	4 mrem/yr
Ra-226 and Ra-228	0	5 pCi/L
Strontium-90		8 pCi/L
Tritium		20,000 pCi/L
Uranium	0	30 ug/L
Disinfectants	MRDLG (mg/L)	MRDL (mg/L)
Chloramines (as Cl ₂)	4	4
Chlorine (as Cl ₂)	4	4
Chlorine dioxide (as ClO ₂)	0.8	0.8

Notes:

(1) USEPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium: 99% removal
- Giardia lamblia: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- Legionella: No limit, but USEPA believes that if Giardia and viruses are removed/ inactivated,
 Legionella will also be controlled
- Turbidity: At no time can turbidity exceed 1 NTU and must not exceed 0.3 NTU in 95% of daily samples in any month
- HPC: No more than 500 bacterial colonies/mL

- (2) More than 5.0% samples total coliform-positive in a month. For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month. Every sample that has total coliform must be analyzed for either fecal coliforms or Escherichia coli if two consecutive TC-positive samples, and one is also positive for E.coli fecal coliforms, system has an acute MCL violation.
- (3) MFL = million fibers per liter, with fiber length >10 μ m.
- (4) Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.
- (5) Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:
 - Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
 - Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

Definitions:

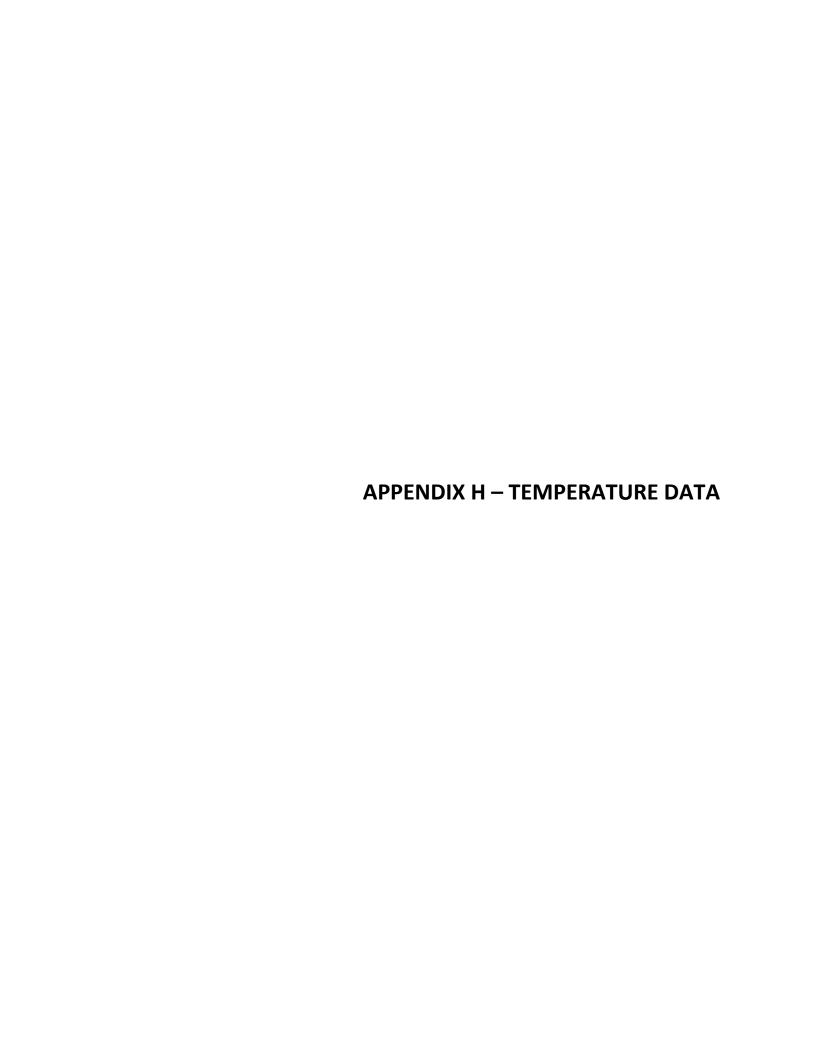
- Maximum Contaminant Level Goal (MCLG) The level of a contaminant in drinking water below
 which there is no known or expected risk to health. MCLGs allow for a margin of safety and are
 non-enforceable public health goals.
- <u>Maximum Contaminant Level</u> (MCL) The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG) The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- <u>Treatment Technique</u> A required process intended to reduce the level of a contaminant in drinking water.
- <u>Maximum Residual Disinfectant Level</u> (MRDL) The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

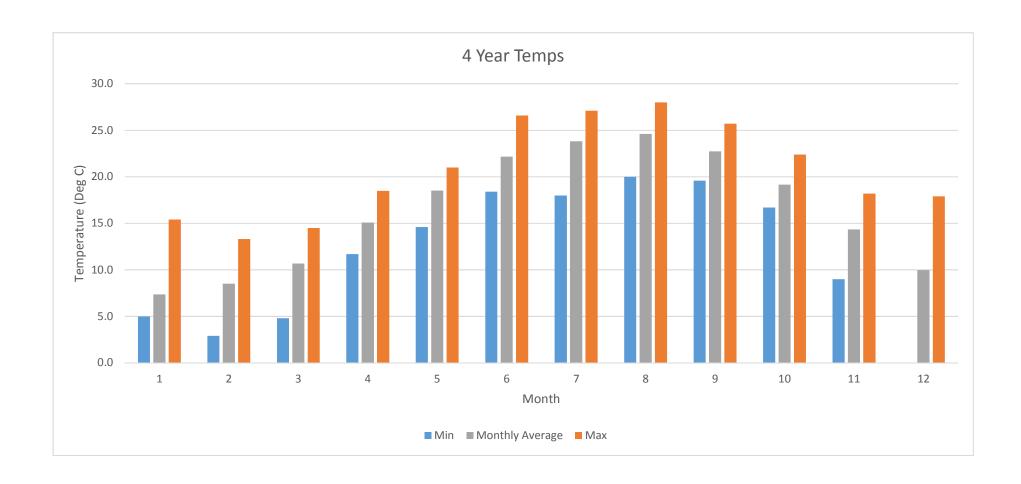
Table G.2 Contaminants and Secondary Drinking Water Standards

Constituent	Effect (s)	Secondary Standard (mg/L)
Aluminum	Colored water	0.05 - 0.2
Chloride	Salty taste	250
Color (color units)	Visible tint	15 color units
Copper	Metallic taste; blue-green stain	1.0
Corrosivity	Metallic taste; corrosion; fixture staining	Non-corrosive
Fluoride ¹	Tooth discoloration	2
Foaming Agents (MBAs)	Frothy, cloudy; bitter taste; odor	0.5
Iron	Rusty color; sediment; metallic taste; reddish or orange staining	0.3
Manganese	Black-to-brown color; black staining; bitter, metallic taste	0.05
Odor, threshold (odor units)	"Rotten egg," musty, or chemical smell	3 threshold odor number (TON)
рН	Low pH: bitter metallic taste, corrosion; high pH: slippery feel, soda taste, deposits	6.5-8.5
Silver	Skin discoloration; greying of the white part of the eye	0.1
Sulfate	Salty taste	250
Total Dissolved Solids (TDS)	Hardness; deposits; colored water; staining; salty taste	500
Zinc	Metallic taste	5

Notes:

(1) Failure to meet the fluoride secondary standard requires public notification pursuant to KDHE 28-15a-208.





			20:	13					201	.4			2015				2016							
	F	low (MC	GD)	Tem	perature	(Deg C)	Flow (MGD)			Tem	peratur	e (Deg C)	Flow (MGD)			Temperature (Deg C)		(Deg C)	Flow (MGD)			Tem	Temperature (Deg C)	
		Max	Average			Monthly	Min	Max	Average			Monthly	Min	Max	Average			Monthly	Min	Max	Average			Monthly
Month	Min Day	Day	Day	Min	Max	Average	Day	Day	Day	Min	Max	Average	Day	Day	Day	Min	Max	Average	Day	Day	Day	Min	Max	Average
January	40.3	47.1	43.4	7.6	10.1	8.7	39.9	49.1	43.5	5.5	8.8	7.2	36.5	47.9	42.5	5.7	9.2	6.9	38.0	44.8	41.6	5.0	15.4	6.7
February	36.2	46.2	42.1	8.6	11.7	10.3	38.5	46.5	41.6	6.2	9.7	8.3	32.0	46.4	41.1	2.9	8.8	5.7	39.2	49.0	41.9	5.7	13.3	9.7
March	37.9	46.2	42.1	8.8	13.4	11.1	33.7	45.5	41.0	5.0	14.3	9.5	36.3	50.4	42.0	4.8	13.9	9.4	34.7	47.8	42.6	11.1	14.5	13.0
April	40.6	49.7	43.8	11.7	16.4	13.7	39.5	61.2	47.8	13.2	17.8	15.1	38.3	58.5	47.9	13.9	18.5	16.5	46.1	58.4	50.7	14.5	15.8	15.0
May	40.1	56.1	47.8	15.7	19.9	18.2	44.9	80.7	63.4	14.6	21.0	18.9	31.0	59.2	45.5	16.9	19.8	18.4						
June	44.7	77.6	59.0	18.4	21.0	19.4	44.5	66.4	52.9	20.3	26.1	23.7	42.7	75.9	59.5	19.7	26.6	23.4						
July	46.8	87.3	64.7	18.0	20.9	19.8	48.8	80.1	62.0	24.6	26.7	25.5	46.1	74.5	63.1	24.7	27.1	26.1						
August	36.1	77.8	54.6	20.0	23.1	21.8	50.4	82.4	68.2	25.2	27.1	26.0	45.1	65.8	58.1	23.8	28.0	26.1						
September	48.7	78.5	66.3	20.5	22.7	21.8	56.1	76.6	65.9	19.6	25.7	22.4	51.1	71.3	59.8	22.6	25.3	24.1						
October	40.8	63.1	53.6	16.7	21.2	18.5	46.3	65.1	55.3	17.6	21.6	19.0	44.6	68.1	55.6	16.8	22.4	19.9						
November	35.4	47.9	42.4	11.8	16.9	14.2	35.5	49.9	44.1	9.0	18.2	13.7	33.1	60.2	46.4	12.5	17.2	15.1						
December	37.5	47.5	42.4	5.7	16.8	9.8	35.4	46.5	40.6	6.6	13.2	10.4	33.8	47.3	42.6	7.0	17.9	9.7						
Yearly	35.4	87.3	50.2	5.7	23.1	15.9	33.7	82.4	52.3	5.0	27.1	16.7	31.0	75.9	50.4	2.9	28.0	16.8	34.7	58.4	42.7	5.0	15.8	10.2



RAW WATER SYSTEM:

BASE OPTION

VERTICAL AND LINEAR IMPROVEMENTS

Table 14.5
Raw Water Vertical Improvements - Opinions of Probable Construction Cost: Base Option

		Diamaina Ctant		Capital Cost Components						
CIP Designation ¹	Trigger	Planning Start Year	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴			
2018 Capital Improvements										
2018-Pressure Control Building-H-1	Hydraulic	2017	LS	\$2,000,000	\$800,000	\$400,000	\$3,200,000			
		2025 Capital II	mprovements							
2020-Bank Storage Wells-RC-1	Redundancy/Capacity	2017	LS	\$7,720,000	\$3,090,000	\$1,550,000	\$12,400,000			
2022-Recharge Recovery Wells-RC-2	Redundancy/Capacity	2019	LS	\$35,260,000	\$14,110,000	\$7,060,000	\$56,430,000			
2022-Recharge Basins-RC-3	Redundancy/Capacity	2019	LS	\$2,090,000	\$840,000	\$420,000	\$3,350,000			
	Subtotal 2025 Capital Cost Opinion \$7									

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: C = Capacity; R = Redundancy; or RC for both.
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

Table 14.6
Raw Water Linear Improvements - Opinions of Probable Construction Cost: Base Option

Year (TBD) Capital Improvements											
		Planning Start			Capital Cost	Components					
CIP Designation ¹	Trigger	Year ⁵	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴				
TBD-EBWF 66" Transmission-R-1	Redundancy	TBD	LS	\$56,940,000	56,940,000 \$22,780,000 \$11,390,000						
					Subtotal Cap	oital Cost Opinion	\$91,110,000				
		Year (TBD) Capita	I Improvements								
TBD-60" & 66"Cheney Transmission-R-2	Redundancy	TBD	LS	\$94,860,000	\$37,950,000	\$18,980,000	\$151,790,000				
					Subtotal Cap	\$151,790,000					

Notes:

- CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
 Trigger: C = Capacity; R = Redundancy; or RC for both.
- Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- Capital cost opinion includes construction, contingency, and design components.
- 5. Planning start year and completion year to be determined based on condition assessment and remaining useful life; placeholder in 2025 for EBWF transmission and in 2030 for Cheney transmission.

City of Wichita, Kansas Burns and McDonnell

Raw Water Capital Planning Schedule: Base Option, Linear Improvements

	TBD-EBWF 66" Transmission-R-1												
Equipment								Trigger		CIP Year			
66" from SE Crosstie to 21st & Zoo Blvd Redundancy										2025			
36" from 29th and Hoover to MWTP Redundancy										2025			
Land Acquisition Redundancy									2025				
Capital Cost Opinion Components				Total									
Capital Cost Opinion Components		TBD		TBD		TBD		TBD		\$			
Engineering Cost (20%)	\$	5,695,000	\$	5,695,000					\$	11,390,000			
Construction Cost			\$	18,980,000	\$	18,980,000	\$	18,980,000	\$	56,940,000			
Contingency (40%)			\$	7,593,300	\$	7,593,300	\$	7,593,300	\$	22,780,000			
Total Capital Cost	\$	5,695,000	\$	32,268,300	\$	26,573,300	\$	26,573,300	\$	91,110,000			

TBD-60" & 66"Cheney Transmission-R-2											
Equipment	Trigger			CIP Year							
60-inch Transmission Main (from Chen	Redundancy			2030							
66-inch Transmission Main (from 21st	ssion))	Redundancy			2030						
Trenching and Backfilling	Redundancy			2030							
Trenchless Installations	Redundancy			2030							
Valves and Accessories	Redundancy			2030							
Connections		Redundancy			2030						
Surface Restoration							Redundancy			2030	
Capital Cost Opinion Components	Year ⁵									Total	
Capital cost opinion components		TBD		TBD		TBD	TBD			\$	
Engineering Cost (20%)	\$	9,490,000	\$	9,490,000					\$	18,980,000	
Construction Cost			\$	31,620,000	\$	31,620,000	\$	31,620,000	\$	94,860,000	
Contingency (40%)			\$	12,650,000	\$	12,650,000	\$	12,650,000	\$	37,950,000	
Total Capital Cost	\$	9,490,000	\$	53,760,000	\$	44,270,000	\$	44,270,000	\$	151,790,000	

Notes:

- 1. CIP Designation definition = CIP Year (TBD)-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016 is 11371.
- 5. Planning start year and completion year to be determined based on condtion assessment and remaining useful life.

City of Wichita, Kansas Burns and McDonnell

2020 Raw Water Capital Planning Schedule: Base Option, Vertical Improvements

2018-Pressure Control Building-H-1											
Equipment					Trigger		CIP Year				
Sleeve valves			Hydraulic		2018						
lock building (mechanical, electrical, I&C, structural, civil) Hydraulic							2018				
nterior and exterior 30" and 60" piping, fittings, and valves. Hydraulic							2018				
SWTP Bypass Piping					Hydraulic		2018				
Canital Cast Oninian Components					Total						
Capital Cost Opinion Components			2017		2018		\$				
Engineering Cost (20%)		\$	200,000	\$	200,000	\$	400,000				
Construction Cost		\$	1,000,000	\$	1,000,000	\$	2,000,000				
Contingency (40%)		\$	267,000	\$	267,000	\$	800,000				
Total Capital Cost		\$	1,467,000	\$	1,467,000	\$	3,200,000				

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016 is 11371.
- 6. This improvement is recommended for completion before the East WTP Improvements (tentatively estimated for completion 2019) project requires shifting the raw water blending location from upstream of the sleeve valves to downstream of the sleeve valves.

2020 Raw Water Capital Planning Schedule: Base Option, Vertical Improvements

2020-Bank Storage Wells-RC-1											
Equipment							Trigger		CIP Year		
Bank Storage Wells							Redundancy/Capacity		2020		
Distribution Piping							Redundancy/Capacity		2020		
Power/Electrical							Redundancy/Capacity		2020		
SWTP Bypass Piping							Redundancy/Capacity		2020		
Canital Cast Oninian Companyons					Υ	ear			Total		
Capital Cost Opinion Components		2017 2018 2019				2020		\$			
Engineering Cost (20%)	\$	775,000	\$	775,000				\$	1,550,000		
Construction Cost			\$	2,573,300	\$	2,573,300	\$ 2,573,300	\$	7,720,000		
Contingency (40%)			\$	1,030,000	\$	1,030,000	\$ 1,030,000	\$	3,090,000		
Total Capital Cost	\$	775,000	\$	4,378,300	\$	3,603,300	\$ 3,603,300	\$	12,400,000		

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016 is 11371.

2022 Raw Water Capital Planning Schedule: Base Option, Vertical Improvements

2022-Recharge Recovery Wells-RC-2											
Equipment				Trigger	CIP Year						
Wells				Redundancy/Capacity	2022						
Well Building (w/pumps, piping, etc)	Redundancy/Capacity	2022									
Electrical	Redundancy/Capacity	2022									
Site Work	Redundancy/Capacity	2022									
Land Acquisition	Redundancy/Capacity	2022									
Power Transmission		Redundancy/Capacity	2022								
Rural/Raw Water Piping/Transmission	Network			Redundancy/Capacity	2022						
Capital Cost Opinion Components			Year		Total						
Capital Cost Opinion Components	2019	2020	2021	2022	\$						
Engineering Cost (20%)	\$ 3,530,000	\$ 3,530,000			\$ 7,060,000						
Construction Cost		\$ 11,753,300	\$ 11,753,300	\$ 11,753,300	\$ 35,260,000						
Contingency (40%)		\$ 4,703,300	\$ 4,703,300	\$ 4,703,300	\$ 14,110,000						
Total Capital Cost	\$ 3,530,000	\$ 19,986,600	\$ 16,456,600	\$ 16,456,600	\$ 56,430,000						

2022-Recharge Basins-RC-3											
Equipment		Trigger							CIP Year		
2 Recharge Basins							Red	undancy/Capacity		2022	
Canital Cast Oninian Commonants		Year								Total	
Capital Cost Opinion Components	2019		2020		2021		2022			\$	
Engineering Cost (20%)	\$	210,000	\$	210,000					\$	420,000	
Construction Cost			\$	696,700	\$	696,700	\$	696,700	\$	2,090,000	
Contingency (40%)			\$	280,000	\$	280,000	\$	280,000	\$	840,000	
Total Capital Cost	\$	210,000	\$	1,186,700	\$	976,700	\$	976,700	\$	3,350,000	

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016 is 11371.

WATER TREATMENT PLANT:

BASE OPTION

VERTICAL IMPROVEMENTS

Table 14.7 Water Treament Vertical Improvements - Opinions of Probable Construction Cost: Base Option

2018 Capital Improvements										
		Planning Start		Capital Cost Components						
CIP Designation ¹	Trigger	Year	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴			
2018-Washwater Process Improvements-C-2	Capacity	2017	LS	\$2,250,000	\$680,000	\$340,000	\$3,270,000			
2018-Filter Improvements-C-4	Capacity	2017	LS	\$5,630,000	\$1,690,000	\$850,000	\$8,170,000			
2018-VPS Hess HSPS-RR-1	Replacement	2017	LS	\$220,000	\$70,000	\$30,000	\$320,000			
2018-Hess Reservoir Recirculation-WQ-1	Water Qaulity	2017	LS	\$239,000	\$100,000	\$50,000	\$389,000			
Subtotal 2018 Capital Cost Opinion										
	2020 Capital Improvements									
2020-On-Site Sodium Hypochlorite Generation-RG-1		2019	LS	\$10,900,000	\$70,000	\$1,640,000	\$15,810,000			
Subtotal 2020 Capital Cost Opinion										

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: C = Capacity, R = Redundancy; RR = Replacement; WQ = water quality.

 2. Contingency at 30 percent of the construction cost.
- 3. Design at 15 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

 5. Base option does not include a new WTP.

City of Wichita, Kansas Burns and McDonnell

2018 WTP Capital Planning Schedule: Base Option

2018-Washv	vatei	Process Im	pro	vements-C-2			
Equipment			Trigger	CIP Year			
Washwater Pumps		Capacity		2018			
Piping				Capacity		2018	
3.0 MGD Gravity Sludge Thickener				Capacity		2018	
Capital Cost Opinion Components		Y	ear		Total		
Capital Cost Opinion Components		2017		2018		\$	
Engineering Cost (15%)	\$	340,000			\$	340,000	
Construction Cost			\$	2,250,000	\$	2,250,000	
Contingency (30%)			\$	680,000	\$	680,000	
Total Capital Cost	\$	340,000	\$	2,930,000	\$	3,270,000	

2018	-Filte	er Improven	nent	:s-C-4	
Equipment		Trigger	CIP Year		
Media Removal				Capacity	2018
New Media				Capacity	2018
Media Install & Backwash Test				Capacity	2018
Underdrain Equipment				Capacity	2018
Prep and Cap Installation				Capacity	2018
Sand and Anthracite Install				Capacity	2018
Startup				Capacity	2018
Disposal				Capacity	2018
Disinfection and Bacti Testing				Capacity	2018
Chemical Feed Equipment				Capacity	2018
Chemical Storage		Capacity			2018
Instrumentation and Controls				Capacity	2018
Piping and Valves				Capacity	2018
Replacement 48-Inch Butterfly Valves				Capacity	2018
Replacement 36-Inch Butterfly Valves				Capacity	2018
Replacement 20-Inch Butterfly Valves				Capacity	2018
Capital Cost Opinion Components		Υ	ear		Total
Capital Cost Opinion Components		2017		2018	\$
Engineering Cost (15%)	\$	850,000			\$ 850,000
Construction Cost			\$	5,630,000	\$ 5,630,000
Contingency (30%)			\$	1,690,000	\$ 1,690,000
Total Capital Cost	\$	850,000	\$	7,320,000	\$ 8,170,000

2018 WTP Capital Planning Schedule: Base Option

203	18-V	PS Hess HSP	S-R	R-1		
Equipment		Trigger	CIP Year			
Vacuum Priming System		Replacement		2018		
Control		Replacement		2018		
Non-skid Piping and Valves				Replacement		2018
Piping and Valves		Replacement	2018			
Capital Cost Opinion Components		Y	ear			Total
Capital Cost Opinion Components		2017		2018		\$
Engineering Cost (15%)	\$	30,000			\$	30,000
Construction Cost			\$	220,000	\$	220,000
Contingency (30%)			\$	70,000	\$	70,000
Total Capital Cost	\$	30,000	\$	290,000	\$	320,000

2018-Hess	2018-Hess Reservoir Recirculation-WQ-1										
Equipment				Trigger	CIP Year						
2 Submersible Pumps		٧	Vater Quality		2018						
12-inch discharge piping and valves			٧	Vater Quality		2018					
Demolition		٧	Vater Quality		2018						
Miscellaneous structural and electrical			Water Quality			2018					
Capital Cost Opinion Components		Y	ear			Total					
Capital Cost Opinion Components		2017		2018		\$					
Engineering Cost (15%)	\$	50,000			\$	50,000					
Construction Cost			\$	239,000	\$	239,000					
Contingency (30%)			\$	100,000	\$	100,000					
Total Capital Cost	\$	50,000	\$	339,000	\$	390,000					

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency at 30 percent of the construction cost.
- 3. Design at 15 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Base option does not include a new WTP.
- 6. Construction cost index for Kansas City, Q2 2016 is 11371.

2020 WTP Capital Planning Schedule: Base Option

2020-On-Site Sodium F	Іур	ochlorite	Generation-	RG-1
Equipment			Trigger	CIP Year
Storage Building				2020
On-Site Hypochlorite Generation Equip	mer	nt		2020
On-Sit Hypochlorite Generation Storage	nks		2020	
Instrumentation and Controls			2020	
Electrical			2020	
Piping				2020
Sitework				2020
Capital Cost Opinion Components		Υe	ear	Total
Capital Cost Opinion Components		2019	2020	\$
Engineering Cost (15%)	\$	1,640,000		\$ 1,640,000
Construction Cost			\$ 10,900,000	\$ 10,900,000
Contingency (30%)			\$ 3,270,000	\$ 3,270,000
Total Capital Cost	\$	1,640,000	\$ 14,170,000	\$ 15,810,000

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency at 30 percent of the construction cost.
- 3. Design at 15 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Base conditions do not include a new WTP.
- 6. Construction cost index for Kansas City, Q2 2016 is 11371.

City of Wichita, Kansas Burns and McDonnell

DISTRIBUTION SYSTEM:

BASE OPTION

VERTICAL IMPROVEMENTS

Table 14.9
Distribution System Vertical Improvements - Opinions of Probable Construction Cost: Base Option

	2035 Capital Improvements											
				Planning Start		Capital Cost	Components					
CIP Designation ¹	Trigger	Туре	Unit		Construction	Cti2	D:3	Capital Cost				
	Year		rear	Construction	Contingency ²	Design ³	Opinion ⁴					
2035-West Maple BPS-H-1	Hydraulic	Pump	LS	2034	\$15,000	\$6,000	\$3,000	\$24,000				
2035-SE BPS-H-1	Hydraulic	Pump	LS	2032	\$310,000	\$120,000	\$60,000	\$490,000				
Subtotal 2035 Capital Cost Opinion \$5												

- CIP Designation definition = CIP Year-Pump Station-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven)
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Base conditions do not include a new WTP.

City of Wichita, Kansas Burns and McDonnell

	2035-West Maple BPS-H-1										
Name	Unit	Туре	Trigger	Pump Station	CIP Year						
2035-West Maple BPS-H-1 LS pump Hydraulic West Maple 2035											

Canital Cost Oninion Components		Year								Total
Capital Cost Opinion Components	2032	2		2033	2034 2035			2035		\$
Design Cost (20%)					\$	3,000			\$	3,000
Construction Cost							\$	15,000	\$	15,000
Contingency (40%)							\$	6,000	\$	6,000
Total Capital Cost	\$	-	\$	-	\$	3,000	\$	21,000	\$	24,000

	2035-SE BPS-H-1										
Name	Unit	Туре	Trigger	Pump Station	CIP Year						
2035-SE BPS-H-1	LS	pump	Hydraulic	Southeast	2035						

Canital Cost Oninion Components		Year							
Capital Cost Opinion Components	2032	2033		2034		2035		\$	
Design Cost (20%)			\$	60,000			\$	60,000	
Construction Cost			\$	155,000	\$	155,000	\$	310,000	
Contingency (40%)			\$	60,000	\$	60,000	\$	120,000	
Total Capital Cost	\$ -	\$ -	\$	275,000	\$	215,000	\$	490,000	

- 1. CIP Designation definition = CIP Year-Pump Station-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven)
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Base conditions do not include a new WTP.

DISTRIBUTION SYSTEM:

BASE OPTION

LINEAR IMPROVEMENTS

Table 14.8
Distribution System Linear Improvements - Opinions of Probable Construction Cost: Base Option

		T .	Τ	ı	2017 Capi Water Main De	tal Improvements	ı	Ca	pital Cost Compone	ante	
CIP Designation ¹	Trigger	Model ID	Unit	Diameter	Quantity	Unit Cost ⁴	Planning Start	Construction ⁵	Contingency ⁶	Design ⁷	Capital Cost
2017-Hess-H-1	Hydraulic	PIPE739	LF	(in) 24	344	(\$/dia-inch*LF) \$9.35	Year 2017	\$77,100	\$30,800	\$15,400	Opinion ⁸ \$123,000
					2020 Cani	tal Improvements			Subtotal 2017 Ca	pital Cost Opinio	n \$123,000
2020-Hess-H-1	Hydraulic	PIPE677	LF	8	70	\$9.35	2019	\$5,200	\$2,100	\$1,000	\$8,300
2020-Hess-H-2 2020-Hess-H-3	Hydraulic Hydraulic	PIPE705 PIPE719	LF LF	8 8	64 165	\$9.35 \$9.35	2019 2019	\$4,800 \$12,300	\$1,900 \$4,900	\$1,000 \$2,500	\$7,700 \$19,700
2020-Hess-H-4	Hydraulic	PIPE667	LF	12	58	\$9.35	2019	\$6,500	\$2,600	\$1,300	\$10,400
2020-Hess-H-5 2020-Hess-H-6	Hydraulic Hydraulic	PIPE713 PIPE715	LF LF	12 12	149 80	\$9.35 \$9.35	2019 2019	\$16,700 \$9,000	\$6,700 \$3,600	\$3,300 \$1,800	\$26,700 \$14,400
2020-Hess-H-7	Hydraulic	PIPE671	LF	16	100	\$9.35	2019	\$14,900	\$6,000	\$3,000	\$23,900
2020-Hess-H-8 2020-Hess-H-9	Hydraulic Hydraulic	PIPE717 PIPE679	LF LF	16 24	174 19	\$9.35 \$9.35	2019 2019	\$26,100 \$4,200	\$10,400 \$1,700	\$5,200 \$1,000	\$41,700 \$6,900
2020-Hess-H-10	Hydraulic	PIPE683	LF	24	97	\$9.35	2019	\$21,700	\$8,700	\$4,300	\$34,700
2020-Hess-H-12	Hydraulic	PIPE691	LF	30	2,883	\$9.35	2017	\$808,700	\$323,500	\$161,700	\$1,293,900
2020-Hess-H-13 2020-Hess-H-14	Hydraulic Hydraulic	PIPE669 PIPE787	LF LF	36 8	53 115	\$9.35 \$9.35	2019 2019	\$17,700 \$8,600	\$7,100 \$3,400	\$3,500 \$1,700	\$28,300 \$13,700
2020-Hess-H-15	Hydraulic	PIPE663	LF	30	5,173	\$9.35	2017	\$1,451,000	\$580,400	\$290,200	\$2,321,600
2020-Hess-H-16 2020-Hess-H-18	Hydraulic Hydraulic	PIPE851 PIPE637	LF LF	48 12	996 4,456	\$9.35 \$4.50	2017 2017	\$447,000 \$240,600	\$178,800 \$96,200	\$89,400 \$48,100	\$715,200 \$384,900
2020-Hess-H-19	Hydraulic	PIPE641	LF	12	2,848	\$4.50	2017	\$153,800	\$61,500	\$30,800	\$246,100
2020-Hess-G-20 2020-East-H-1	Growth Hydraulic	PIPE591 PIPE681	LF LF	24 16	2,307 25	\$4.50 \$9.35	2020 2019	\$249,200 \$3,800	\$99,700 \$1,500	\$49,800 \$1,000	\$398,700 \$6,300
2020-East-H-2	Hydraulic	PIPE659	LF	30	3,460	\$9.35	2017	\$970,600	\$388,200	\$194,100	\$1,552,900
2020-Hess-F-1 2020-Hess-F-5	Fire Fire	PIPE755 PIPE765	LF LF	8	731 1,026	\$9.35 \$9.35	2019 2017	\$54,600 \$76,800	\$21,800 \$30,700	\$10,900 \$15,400	\$87,300 \$122,900
2020-Hess-F-8	Fire	PIPE771	LF	8	592	\$9.35	2019	\$44,300	\$17,700	\$8,900	\$70,900
2020-Hess-F-11 2020-Hess-F-12	Fire Fire	PIPE577 PIPE579	LF LF	12 12	5,241 1,613	\$4.50 \$4.50	2017 2017	\$283,000 \$87,100	\$113,200 \$34,800	\$56,600 \$17,400	\$452,800 \$139,300
2020-Hess-F-13	Fire	PIPE581	LF	12	1,661	\$4.50	2017	\$89,700	\$35,900	\$17,900	\$143,500
2020-Hess-F-14 2020-Hess-F-15	Fire Fire	PIPE583 PIPE775	LF LF	12 12	3,612 536	\$4.50 \$9.35	2017 2019	\$195,000 \$60,200	\$78,000 \$24,100	\$39,000 \$12,000	\$312,000 \$96,300
2020-Hess-F-18	Fire	PIPE857	LF	8	186	\$9.35	2019	\$13,900	\$5,600	\$2,800	\$22,300
					2035 Cani	tal Improvements			Subtotal 2020 Ca	pital Cost Opinio	n \$8,600,000
2035-Hess-H-1	Hydraulic	PIPE701	LF	8	15	\$9.35	2034	\$1,100	\$500	\$1,000	\$2,600
2035-Hess-H-2	Hydraulic	PIPE703	LF	8	82	\$9.35	2034	\$6,100	\$2,400	\$1,200	\$9,700
2035-Hess-H-3 2035-Hess-H-4	Hydraulic Hydraulic	PIPE721 PIPE665	LF LF	8 12	163 217	\$9.35 \$9.35	2034 2034	\$12,200 \$24,300	\$4,900 \$9,700	\$2,400 \$4,900	\$19,500 \$38,900
2035-Hess-H-6	Hydraulic	PIPE711	LF LF	12 16	62 48	\$9.35	2034	\$7,000	\$2,800	\$1,400	\$11,200
2035-Hess-H-7 2035-Hess-H-8	Hydraulic Hydraulic	PIPE673 PIPE697	LF	16	3,781	\$9.35 \$9.35	2034 2032	\$7,100 \$565,600	\$2,800 \$226,200	\$1,400 \$113,100	\$11,300 \$904,900
2035-Hess-H-9	Hydraulic	PIPE725	LF	16	14	\$9.35	2034	\$2,100	\$800	\$1,000	\$3,900
2035-Hess-H-11 2035-East-H-1	Hydraulic Hydraulic	PIPE699 PIPE709	LF LF	20 12	163 18	\$9.35 \$9.35	2034 2034	\$30,400 \$2,000	\$12,200 \$800	\$6,100 \$1,000	\$48,700 \$3,800
									Subtotal 2035 Ca	pital Cost Opinio	n \$1,050,000
2045-Hess-G-1	Growth	PIPE495	LF	12	2045 Capi 5,436	\$4.50	2042	\$293,500	\$117,400	\$58,700	\$469,600
2045-Hess-G-2	Growth	PIPE497	LF	12	5,229	\$4.50	2042	\$282,400	\$113,000	\$56,500	\$451,900
2045-Hess-G-3 2045-Hess-G-5	Growth Growth	PIPE499 PIPE503	LF LF	12 12	333 4,444	\$4.50 \$4.50	2044 2042	\$18,000 \$240,000	\$7,200 \$96,000	\$3,600 \$48,000	\$28,800 \$384,000
2045-Hess-G-6	Growth	PIPE505	LF	12	5,375	\$4.50	2042	\$290,300	\$116,100	\$58,100	\$464,500
2045-Hess-G-7 2045-Hess-G-8	Growth Growth	PIPE507 PIPE509	LF LF	12 12	4,100 2,853	\$4.50 \$4.50	2042 2042	\$221,400 \$154,100	\$88,600 \$61,600	\$44,300 \$30,800	\$354,300 \$246,500
2045-Hess-G-9	Growth	PIPE511	LF	12	5,334	\$4.50	2042	\$288,000	\$115,200	\$57,600	\$460,800
2045-Hess-G-10 2045-Hess-G-11	Growth Growth	PIPE513 PIPE515	LF LF	12 12	2,653 5,205	\$4.50 \$4.50	2042 2042	\$143,300 \$281,000	\$57,300 \$112,400	\$28,700 \$56,200	\$229,300 \$449,600
2045-Hess-G-12	Growth	PIPE517	LF	12	5,577	\$4.50	2042	\$301,200	\$120,500	\$60,200	\$481,900
2045-Hess-G-13 2045-Hess-G-14	Growth Growth	PIPE519 PIPE525	LF LF	8 12	4,690 5,248	\$4.50 \$4.50	2042 2042	\$168,800 \$283,400	\$67,500 \$113,400	\$33,800 \$56,700	\$270,100 \$453,500
2045-Hess-G-15	Growth	PIPE527	LF	12	5,242	\$4.50	2042	\$283,400	\$113,400	\$56,600	\$452,900
2045-Hess-G-16	Growth	PIPE529	LF LF	12 12	5,292	\$4.50	2042	\$285,800	\$114,300	\$57,200	\$457,300
2045-Hess-G-17 2045-Hess-G-18	Growth Growth	PIPE531 PIPE533	LF	12	5,187 1,359	\$4.50 \$4.50	2042 2042	\$280,100 \$73,400	\$112,000 \$29,400	\$56,000 \$14,700	\$448,100 \$117,500
2045-Hess-G-19	Growth	PIPE537	LF	12	1,594	\$4.50	2042	\$86,100	\$34,400	\$17,200	\$137,700
2045-Hess-G-21 2045-Hess-G-22	Growth Growth	PIPE541 PIPE547	LF LF	16 12	1,437 2,008	\$4.50 \$4.50	2042 2042	\$103,400 \$108,400	\$41,400 \$43,400	\$20,700 \$21,700	\$165,500 \$173,500
2045-Hess-G-23	Growth	PIPE549	LF	12	5,597	\$4.50	2042	\$302,200	\$120,900	\$60,400	\$483,500
2045-Hess-G-24 2045-Hess-G-25	Growth Growth	PIPE551 PIPE553	LF LF	12 12	5,305 5,535	\$4.50 \$4.50	2042 2042	\$286,500 \$298,900	\$114,600 \$119,600	\$57,300 \$59,800	\$458,400 \$478,300
2045-Hess-G-26	Growth	PIPE555*	LF	12	5,261	\$4.50	2042	\$284,100	\$113,600	\$56,800	\$454,500
2045-Hess-G-27 2045-Hess-G-28	Growth Growth	PIPE557 PIPE559*	LF LF	12 12	5,205 5,035	\$4.50 \$4.50	2042 2042	\$281,100 \$271,900	\$112,400 \$108,800	\$56,200 \$54,400	\$449,700 \$435,100
2045-Hess-G-29	Growth	PIPE561	LF	12	5,296	\$4.50	2042	\$286,000	\$114,400	\$57,200	\$457,600
2045-Hess-G-30 2045-Hess-G-31	Growth Growth	PIPE563 PIPE565	LF LF	12 12	1,690 5,259	\$4.50 \$4.50	2042 2042	\$91,300 \$284,000	\$36,500 \$113,600	\$18,300 \$56,800	\$146,100 \$454,400
2045-Hess-G-34	Growth	PIPE571	LF	16	3,572	\$4.50	2042	\$257,200	\$102,900	\$51,400	\$411,500
2045-Hess-G-37 2045-Hess-G-38	Growth Growth	PIPE585* PIPE587*	LF LF	12 12	5,292 5,237	\$4.50 \$4.50	2042 2042	\$285,800 \$282,800	\$114,300 \$113,100	\$57,200 \$56,600	\$457,300 \$452,500
2045-Hess-G-39	Growth	PIPE589	LF	12	3,469	\$4.50	2042	\$187,300	\$74,900	\$37,500	\$299,700
2045-Hess-G-41 2045-Hess-G-42	Growth Growth	PIPE593 PIPE595*	LF LF	12 12	1,489 5,118	\$4.50 \$4.50	2042 2042	\$80,400 \$276,400	\$32,200 \$110,600	\$16,100 \$55,300	\$128,700 \$442,300
2045-Hess-G-43	Growth	PIPE597	LF	12	5,251	\$4.50	2042	\$283,600	\$113,400	\$56,700	\$453,700
2045-Hess-G-44	Growth	PIPE599	LF LF	12	5,209 5,065	\$4.50 \$4.50	2042	\$281,300	\$112,500 \$109,400	\$56,300	\$450,100 \$437,600
2045-Hess-G-45 2045-Hess-G-46	Growth Growth	PIPE601 PIPE605	LF LF	12 12	5,065 1,231	\$4.50 \$4.50	2042 2042	\$273,500 \$66,500	\$109,400 \$26,600	\$54,700 \$13,300	\$437,600
2045-Hess-G-47 ¹¹	Growth	PIPE607	LF	12	481	\$71.16	2042	\$410,700	\$164,300	\$82,100	\$657,100
2045-Hess-G-48 2045-Hess-G-49	Growth Growth	PIPE609 PIPE611*	LF LF	12 12	5,177 5,363	\$4.50 \$4.50	2042 2042	\$279,600 \$289,600	\$111,800 \$115,800	\$55,900 \$57,900	\$447,300 \$463,300
2045-Hess-G-50	Growth	PIPE613	LF	12	5,223	\$4.50	2042	\$282,000	\$112,800	\$56,400	\$451,200
2045-Hess-G-51 2045-Hess-G-52	Growth Growth	PIPE615 PIPE617	LF LF	12 12	5,250 5,273	\$4.50 \$4.50	2042 2042	\$283,500 \$284,700	\$113,400 \$113,900	\$56,700 \$56,900	\$453,600 \$455,500
2045-Hess-G-52 2045-Hess-G-53	Growth	PIPE617 PIPE619	LF LF	12	5,231	\$4.50	2042	\$284,700	\$113,900	\$56,500	\$455,500
2045-Hess-G-54	Growth	PIPE621	LF	12	5,419	\$4.50	2042	\$292,600	\$117,000	\$58,500	\$468,100
2045-Hess-G-55 2045-Hess-G-56	Growth Growth	PIPE623* PIPE625*	LF LF	12 12	5,323 5,272	\$4.50 \$4.50	2042 2042	\$287,400 \$284,700	\$115,000 \$113,900	\$57,500 \$56,900	\$459,900 \$455,500
2045-Hess-G-57	Growth	PIPE627	LF	12	2,537	\$4.50	2042	\$137,000	\$54,800	\$27,400	\$219,200
2045-Hess-G-58 2045-Hess-G-59	Growth Growth	PIPE629 PIPE631	LF LF	12 12	5,281 4,047	\$4.50 \$4.50	2042 2042	\$285,200 \$218,600	\$114,100 \$87,400	\$57,000 \$43,700	\$456,300 \$349,700
2045-Hess-G-60	Growth	PIPE633	LF	12	2,631	\$4.50	2042	\$142,100	\$56,800	\$28,400	\$227,300
2045-Hess-G-61 2045-Hess-G-63	Growth Growth	PIPE799 PIPE639	LF LF	12 12	2,720 3,181	\$4.50 \$4.50	2042 2042	\$146,900 \$171,800	\$58,800 \$68,700	\$29,400 \$34,400	\$235,100 \$274,900
2045-Hess-G-65	Growth	PIPE639 PIPE777	LF LF	12	2,619	\$4.50	2042	\$171,800	\$68,700	\$34,400	\$274,900
2045-Hess-G-66	Growth Growth	PIPE469	LF	12	3,498	\$4.50	2042	\$188,900	\$75,600	\$37,800	\$302,300
2045-East-G-1		PIPE443	LF	12	2,196	\$4.50	2042	\$118,600	\$47,400	\$23,700	\$189,700

City of Wichita, Kansas

Table 14.8 Distribution System Linear Improvements - Opinions of Probable Construction Cost: Base Option

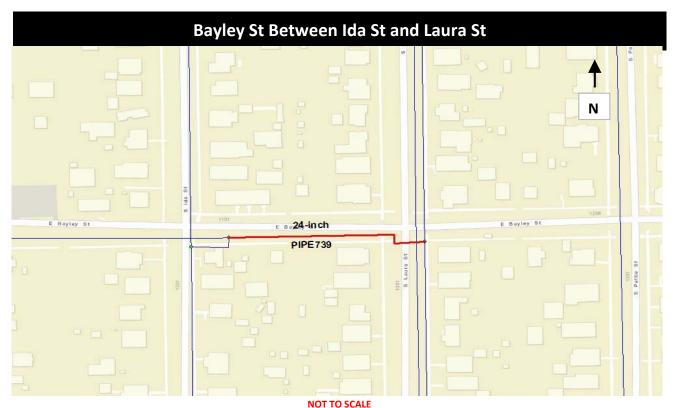
					2017 Capi	tal Improvements					
					Water Main De	tail		Ca	pital Cost Compone	ents	
CIP Designation ¹	Trigger	Model ID	Unit	Diameter (in)	Quantity	Unit Cost⁴ (\$/dia-inch*LF)	Planning Start Year	Construction ⁵	Contingency ⁶	Design ⁷	Capital Cost Opinion ⁸
2045-East-G-3	Growth	PIPE447	LF	12	4,715	\$4.50	2042	\$254,600	\$101,800	\$50,900	\$407,300
2045-East-G-4	Growth	PIPE449*	LF	12	5,148	\$4.50	2042	\$278,000	\$111,200	\$55,600	\$444,800
2045-East-G-5	Growth	PIPE451*	LF	12	5,289	\$4.50	2042	\$285,600	\$114,200	\$57,100	\$456,900
2045-East-G-6	Growth	PIPE453	LF	12	5,178	\$4.50	2042	\$279,600	\$111,800	\$55,900	\$447,300
2045-East-G-7	Growth	PIPE455*	LF	12	5,241	\$4.50	2042	\$283,000	\$113,200	\$56,600	\$452,800
2045-East-G-8	Growth	PIPE457*	LF	12	5,333	\$4.50	2042	\$288,000	\$115,200	\$57,600	\$460,800
2045-East-G-9	Growth	PIPE459*	LF	12	5,270	\$4.50	2042	\$284,600	\$113,800	\$56,900	\$455,300
2045-East-G-10	Growth	PIPE461*	LF	12	5,309	\$4.50	2042	\$286,700	\$114,700	\$57,300	\$458,700
2045-East-G-13	Growth	PIPE467*	LF	12	5,218	\$4.50	2042	\$281,700	\$112,700	\$56,300	\$450,700
2045-East-G-14	Growth	PIPE473	LF	12	1,045	\$4.50	2044	\$56,400	\$22,600	\$11,300	\$90,300
2045-East-G-15	Growth	PIPE475*	LF	12	5,278	\$4.50	2042	\$285,000	\$114,000	\$57,000	\$456,000
2045-East-G-16	Growth	PIPE477*	LF	12	5,476	\$4.50	2042	\$295,700	\$118,300	\$59,100	\$473,100
2045-East-G-17	Growth	PIPE479	LF	12	2,847	\$4.50	2042	\$153,700	\$61,500	\$30,700	\$245,900
2045-East-G-18	Growth	PIPE481*	LF	12	5,279	\$4.50	2042	\$285,100	\$114,000	\$57,000	\$456,100
2045-East-G-19	Growth	PIPE483	LF	12	2,648	\$4.50	2042	\$143,000	\$57,200	\$28,600	\$228,800
2045-East-G-20	Growth	PIPE485	LF	12	5,373	\$4.50	2042	\$290,200	\$116,100	\$58,000	\$464,300
2045-East-G-21	Growth	PIPE487	LF	12	5,411	\$4.50	2042	\$292,200	\$116,900	\$58,400	\$467,500
2045-East-G-22	Growth	PIPE489	LF	12	2,855	\$4.50	2042	\$154,200	\$61,700	\$30,800	\$246,700
2045-Northeast-G-1	Growth	PIPE493	LF	12	8,997	\$4.50	2042	\$485,900	\$194,400	\$97,200	\$777,500
								Subto	tal 2045 Growth Ca	pital Cost Opinion	\$30,040,000

- CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 - Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Fire flow improvements prioritized as funding is available
- 3. Growth improvements prioritized as future development occurs.
- 4. Future growth areas outside City limits (peripheral growth) does not include pavement removal and replacement; future growth areas inside City limits (infill growth) and a

hydraulic and fire flow improvements includes pavement removal and replacement

- 5. Construction cost for horizontal improvements (excludes pump improvements) is based on unit cost
- 6. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 7. Design at 20 percent of the construction cost; minimum design cost is \$1,000. 8. Capital cost opinion includes construction, contingency, and design components.
- 9. Base conditions do not include a new WTP.
- 10. Model IDs with an asterisk (*) represent pipes that extend into neighboring water suppliers or rural water districts where the City has designated some portion therein as a future growth area 11. Unit cost at \$4.50/dia-inch*LF plus \$800/LF for for horizontal boring.





2017-Hess-H-1											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE739	24	344	Hydraulic	Hess	2017						

Capital Cost Opinion		Total						
Components	2017	2018			2019		2020	\$
Design	\$ 7,700	\$	7,700					\$ 15,400
Construction		\$	25,700	\$	25,700	\$	25,700	\$ 77,100
Contingency		\$	10,300	\$	10,300	\$	10,300	\$ 30,800
Annual Planning Cost	\$ 7,700	\$	43,700	\$	36,000	\$	36,000	\$ 123,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Murdock St and Broadway St

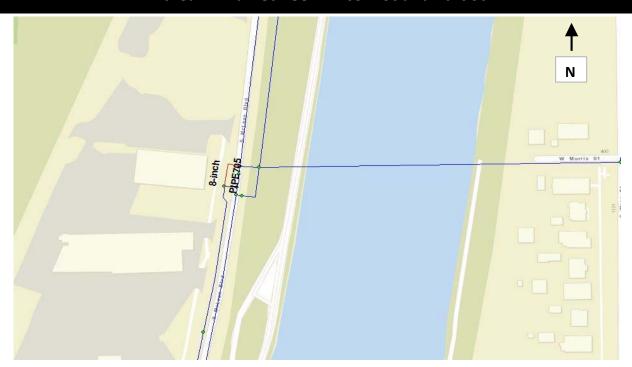


	2020-Hess-H-1											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE677												

Capital Cost Opinion		Year									
Components	2	2017		2018		2019 2020				\$	
Design Cost (20%)					\$	1,000			\$	1,000	
Construction Cost							\$	5,200	\$	5,200	
Contingency (40%)							\$	2,100	\$	2,100	
Total Capital Cost	\$	-	\$	-	\$	1,000	\$	7,300	\$	8,300	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

McLean Blvd Between Lincoln St and Taft St



NOT TO SCALE

	2020-Hess-H-2											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE705	8	64	Hydraulic	Hess	2020							

Capital Cost Opinion Components		Year							
Capital Cost Opinion Components	201	.7	203	L8	2019		2020	\$	
Design Cost (20%)					\$ 1,000			\$	1,000
Construction Cost						\$	4,800	\$	4,800
Contingency (40%)						\$	1,900	\$	1,900
Total Capital Cost	\$	-	\$	-	\$ 1,000	\$	6,700	\$	7,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



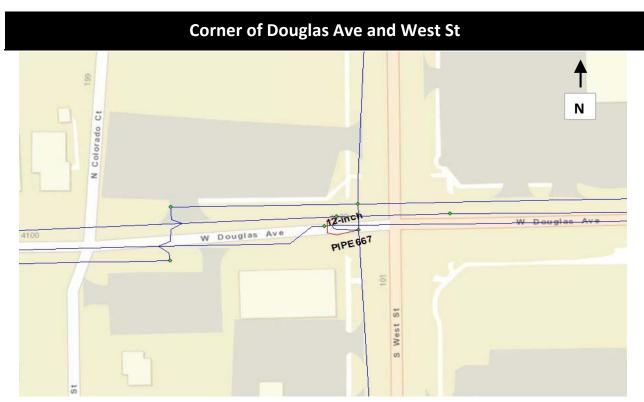


NOT TO SCALE

2020-Hess-H-3										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year					
PIPE719	8	165	Hydraulic	Hess	2020					

Capital Cost Opinion Components		Year							
Capital Cost Opinion Components	201	.7	20	18	2019		2020		\$
Design Cost (20%)					\$ 2,500			\$	2,500
Construction Cost						\$	12,300	\$	12,300
Contingency (40%)						\$	4,900	\$	4,900
Total Capital Cost	\$	-	\$	-	\$ 2,500	\$	17,200	\$	19,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



NOT TO SCALE

	2020-Hess-H-4											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE667	12	58	Hydraulic	Hess	2020							

Capital Cost Opinion Components		Year							
Capital Cost Opinion Components	201	.7	20	18	2019		2020		\$
Design Cost (20%)					\$ 1,300			\$	1,300
Construction Cost						\$	6,500	\$	6,500
Contingency (40%)						\$	2,600	\$	2,600
Total Capital Cost	\$	-	\$	-	\$ 1,300	\$	9,100	\$	10,400

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Lincoln St and Fabrique St



	2020-Hess-H-5										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE713	12	149	Hydraulic	Hess	2020						

consider pairing with CIP 2020-Hess-H-15

Conital Cost Oninion Components		Year							
Capital Cost Opinion Components	201	L7	2018		2019		2020		\$
Design Cost (20%)				\$	3,300			\$	3,300
Construction Cost						\$	16,700	\$	16,700
Contingency (40%)						\$	6,700	\$	6,700
Total Capital Cost	\$	-	\$ -	\$	3,300	\$	23,400	\$	26,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Woodlawn St and Lincoln St



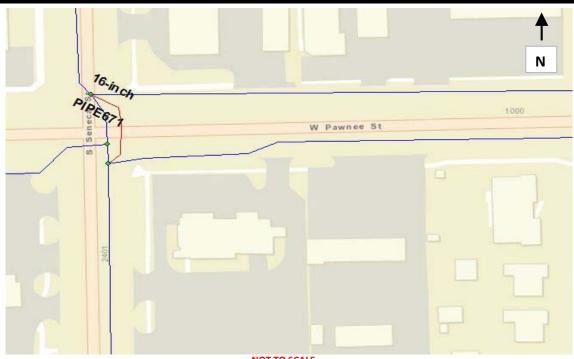
	2020-Hess-H-6										
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE715	12	80	Hydraulic	Hess	2020						

consider pairing with CIP 2020-Hess-H-15

Canital Cast Oninian Components				Ye	ear			Total \$		
Capital Cost Opinion Components	2	017	201	8		2019	2020			
Design Cost (20%)					\$	1,800		\$	1,800	
Construction Cost							\$ 9,000	\$	9,000	
Contingency (40%)							\$ 3,600	\$	3,600	
Total Capital Cost	\$	-	\$	-	\$	1,800	\$ 12,600	\$	14,400	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Seneca St and Pawnee St



NOT TO SCALE

	2020-Hess-H-7										
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE671	16	100	Hydraulic	Hess	2020						

Conital Cost Oninion Components			Total					
Capital Cost Opinion Components		2017	:	2018	2019	2020		\$
Design Cost (20%)					\$ 3,000		\$	3,000
Construction Cost						\$ 14,900	\$	14,900
Contingency (40%)						\$ 6,000	\$	6,000
Total Capital Cost	\$	-	\$	-	\$ 3,000	\$ 20,900	\$	23,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

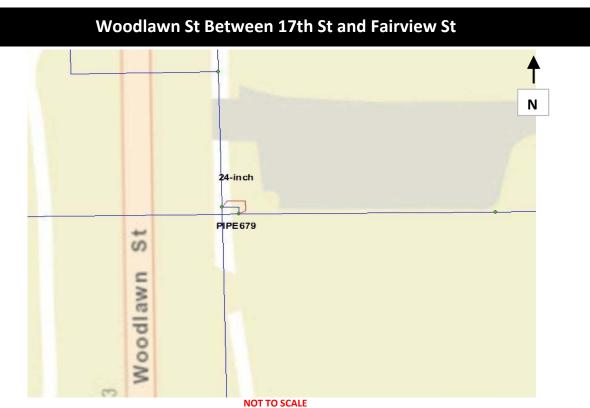
Corner of Murdock St and Emporia St



	2020-	Hess-H-8						
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressur							
PIPE717	16	174	Hydraulic	Hess	2020			

Conital Cost Opinion Components			Total					
Capital Cost Opinion Components		2017	:	2018	2019	2020		\$
Design Cost (20%)					\$ 5,200		\$	5,200
Construction Cost						\$ 26,100	\$	26,100
Contingency (40%)						\$ 10,400	\$	10,400
Total Capital Cost	\$	-	\$	-	\$ 5,200	\$ 36,500	\$	41,700

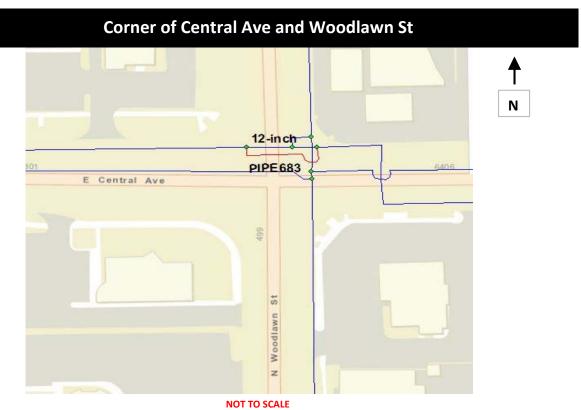
- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



	2020-	Hess-H-9								
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE679	24	19	Hydraulic	Hess	2020					

Canital Cast Opinion Components				Υ	ear			Total	
Capital Cost Opinion Components		2017	1	2018		2019	2020		\$
Design Cost (20%)					\$	1,000		\$	1,000
Construction Cost							\$ 4,200	\$	4,200
Contingency (40%)							\$ 1,700	\$	1,700
Total Capital Cost	\$	-	\$	-	\$	1,000	\$ 5,900	\$	6,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

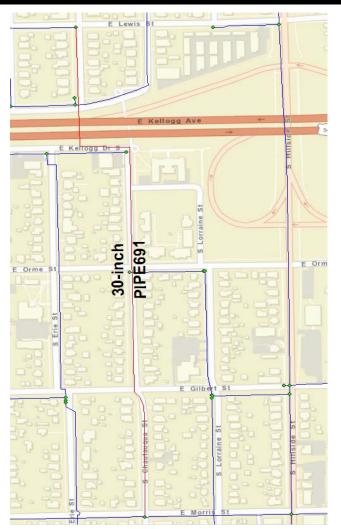


2020-Hess-H-10										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE683	24	97	Hydraulic	Hess	2020					

Canital Cast Opinion Components		Year							
Capital Cost Opinion Components	201	L 7	2018	2019		2020		\$	
Design Cost (20%)				\$ 4,30	0		\$	4,300	
Construction Cost					\$	21,700	\$	21,700	
Contingency (40%)					\$	8,700	\$	8,700	
Total Capital Cost	\$	-	\$ -	\$ 4,30	0 \$	30,400	\$	34,700	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

On Erie St and S Chautauqua St from E Lewis St to E Morris St





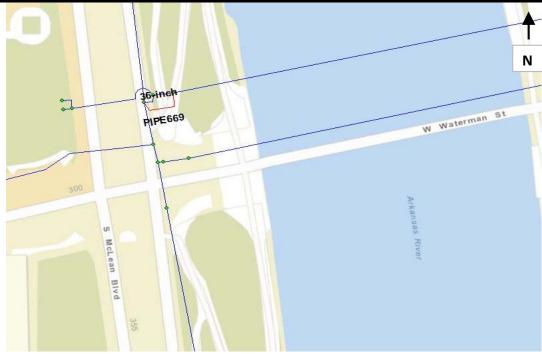
NOT TO SCALE

	2020-Hess-H-12											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE691	30	2883	Hydraulic	Hess	2020							

Capital Cost Opinion Components			Y	ear					Total
Capital Cost Opinion Components	2017		2018		2019		2020		\$
Design Cost (20%)	\$ 80,850	\$	80,850					\$	161,700
Construction Cost		\$	269,567	\$	269,567	\$	269,567	\$	808,700
Contingency (40%)		\$	107,833	\$	107,833	\$	107,833	\$	323,500
Total Capital Cost	\$ 80,850	\$	458,250	\$	377,400	\$	377,400	\$	1,293,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of McLean Blvd and Waterman St

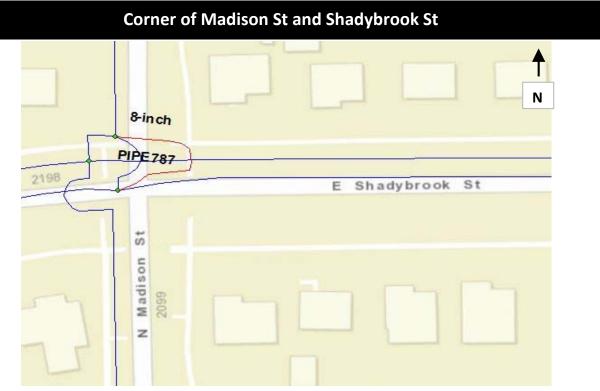


NOT TO SCALE

	2020-Hess-H-13											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE669	36	53	Hydraulic	Hess	2020							

Canital Cast Opinion Components			Total					
Capital Cost Opinion Components		2017	1	2018	2019	2020		\$
Design Cost (20%)					\$ 3,500		\$	3,500
Construction Cost						\$ 17,700	\$	17,700
Contingency (40%)						\$ 7,100	\$	7,100
Total Capital Cost	\$	-	\$	-	\$ 3,500	\$ 24,800	\$	28,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



NOT TO SCALE

	2020-Hess-H-14											
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year												
PIPE787	8	115	Hydraulic	Hess	2020							

Conital Cost Opinion Components	Year								Total
Capital Cost Opinion Components	2017		2018		2019		2020		\$
Design Cost (20%)				\$	1,700			\$	1,700
Construction Cost						\$	8,600	\$	8,600
Contingency (40%)						\$	3,400	\$	3,400
Total Capital Cost	\$ -	\$	-	\$	1,700	\$	12,000	\$	13,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Woodlawn St from Lincoln St to Harry St



2020-Hess-H-15											
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE663	30	5173	Hydraulic	Hess	2020						

Capital Cost Opinion Components				Year						Total
Capital Cost Opinion Components		2017		2018		2019		2020		\$
Design Cost (20%)	\$	145,100	\$	145,100					\$	290,200
Construction Cost			\$	483,700	\$	483,700	\$	483,700	\$	1,451,000
Contingency (40%)			\$	193,500	\$	193,500	\$	193,500	\$	580,400
Total Capital Cost	\$	145,100	\$	822,300	\$	677,200	\$	677,200	\$	2,321,600

- CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Green St to S Erie St

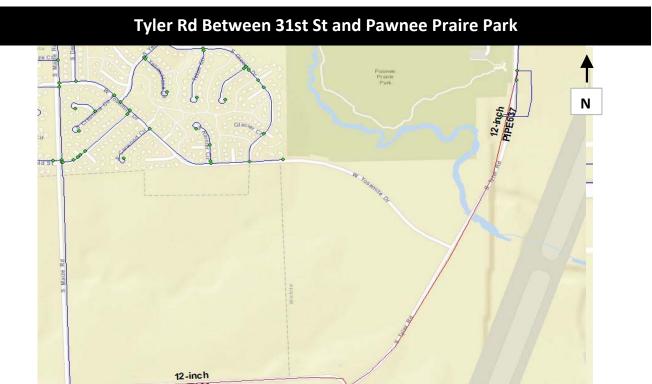


NOT TO SCALE

2020-Hess-H-16												
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE851	48	996	Hydraulic	Hess	2020							

Capital Cost Opinion Components				Year						Total
Capital Cost Opinion Components		2017		2018		2019		2020		\$
Design Cost (20%)	\$	44,700	\$	44,700					\$	89,400
Construction Cost			\$	149,000	\$	149,000	\$	149,000	\$	447,000
Contingency (40%)			\$	59,600	\$	59,600	\$	59,600	\$	178,800
Total Capital Cost	\$	44,700	\$	253,300	\$	208,600	\$	208,600	\$	715,200

- CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

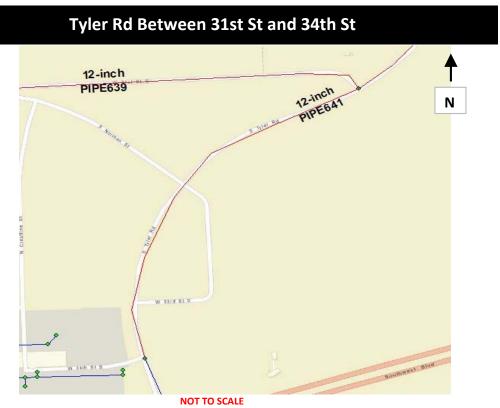


2020-Hess-H-18											
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
Pipe637	12	4456	Hydraulic	Hess	2020						

NOT TO SCALE

Canital Cast Opinion Components		Total				
Capital Cost Opinion Components	2017	2018	2019	2020		\$
Design Cost (20%)	\$ 24,100	\$ 24,100			\$	48,100
Construction Cost		\$ 80,200	\$ 80,200	\$ 80,200	\$	240,600
Contingency (40%)		\$ 32,100	\$ 32,100	\$ 32,100	\$	96,200
Total Capital Cost	\$ 24,100	\$ 136,400	\$ 112,300	\$ 112,300	\$	384,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



	2020-Hess-H-19											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE641	12	12 2848 Hydraulic Hess 20										

Capital Cost Opinion		Total			
Components	2017	2018	2019	2020	\$
Design Cost (20%)	\$ 15,400	\$ 15,400			\$ 30,800
Construction Cost		\$ 51,300	\$ 51,300	\$ 51,300	\$ 153,800
Contingency (40%)		\$ 20,500	\$ 20,500	\$ 20,500	\$ 61,500
Total Capital Cost	\$ 15,400	\$ 87,200	\$ 71,800	\$ 71,800	\$ 246,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

135th St Between Lost Creek St and Central St



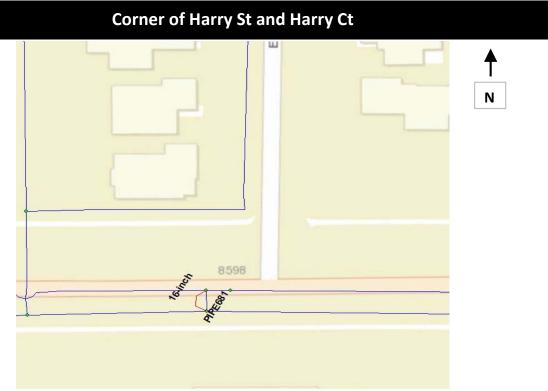


NOT TO SCALE

	2020-	2020-Hess-G-20											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year												
PIPE591 24 2307 Growth Hess													

Capital Cost Opinion Components			Year						Total
Capital Cost Opinion Components	2020		2021		2022		2023		\$
Design Cost (20%)	\$ 24,900	\$	24,900					\$	49,800
Construction Cost		\$	83,067	\$	83,067	\$	83,067	\$	249,200
Contingency (40%)		\$	33,233	\$	33,233	\$	33,233	\$	99,700
Total Capital Cost	\$ 24,900	\$	141,200	\$	116,300	\$	116,300	\$	398,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.
- 6. This project is placed in CIP year 2020 and starting in 2020 to be implemented prior to a road paving project in 2025.



NOT TO SCALE

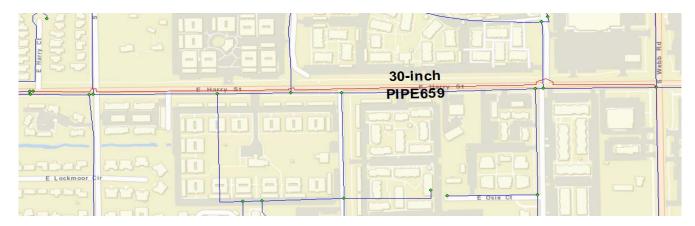
2020-East-H-1												
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE681	16	25	Hydraulic	East	2020							

Conital Cost Opinion Components			Total					
Capital Cost Opinion Components		2017	2018	2019	2020	\$		
Design Cost (20%)				\$ 1,000		\$	1,000	
Construction Cost					\$ 3,800	\$	3,800	
Contingency (40%)					\$ 1,500	\$	1,500	
Total Capital Cost	\$	-	\$ -	\$ 1,000	\$ 5,300	\$	6,300	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Harry St Between Harry Ct and Webb Rd





NOT TO SCALE

	2020-East-H-2											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE659	30	3460	Hydraulic	East	2020							

Capital Cost Opinion Components			Total					
Capital Cost Opinion Components	2017		2018	2019		2020		\$
Design Cost (20%)	\$ 97,050	\$	97,050					\$ 194,100
Construction Cost		\$	323,533	\$	323,533	\$	323,533	\$ 970,600
Contingency (40%)		\$	129,400	\$	129,400	\$	129,400	\$ 388,200
Total Capital Cost	\$ 97,050	\$	549,983	\$	452,933	\$	452,933	\$ 1,552,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Harry St Between Harry Ct and Webb Rd





NOT TO SCALE

2020-East-H- 1, 2											
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE681	16	25	Hydraulic	East	2020						
PIPE659	30	3460	Hydraulic	East	2020						

Canital Cost Opinion Components	Canital Cost Oninion Components Year									Total
Capital Cost Opinion Components		2017		2018		2019		2020		\$
Design Cost (20%)	\$	97,050	\$	97,050	\$	1,000	\$	=	\$	195,100
Construction Cost	\$	-	\$	323,533	\$	323,533	\$	327,333	\$	974,400
Contingency (40%)	\$	-	\$	129,400	\$	129,400	\$	130,900	\$	389,700
Total Capital Cost	\$	97,050	\$	549,983	\$	453,933	\$	458,233	\$	1,559,200

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Old Lawrence Rd Between Carp St and 30th St





NOT TO SCALE

	2020-Hess-F-1											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE755	8	731	Fire Flow	Hess	2020							

Canital Cast Opinion Components			Υ	'ear		Total		
Capital Cost Opinion Components	2017	20	18	2019	2020		\$	
Design Cost (20%)				\$ 10,900		\$	10,900	
Construction Cost				\$ 27,300	\$ 27,300	\$	54,600	
Contingency (40%)				\$ 10,900	\$ 10,900	\$	21,800	
Total Capital Cost	\$ -	\$	-	\$ 49,100	\$ 38,200	\$	87,300	

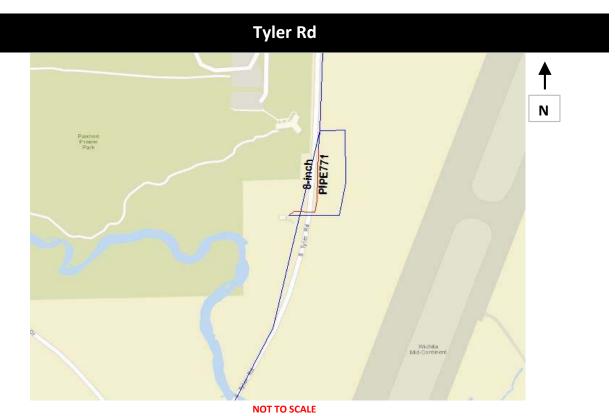
27th St Between Hillside St and Vassar St



NOT TO SCALE

	2020-Hess-F-5											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE765	8	1026	Fire Flow	Hess	2020							

Canital Cast Opinion Components				Total					
Capital Cost Opinion Components	2017		2018		2019		2020	\$	
Design Cost (20%)	\$ 7,700	\$	7,700					\$	15,400
Construction Cost		\$	25,600	\$	25,600	\$	25,600	\$	76,800
Contingency (40%)		\$	10,200	\$	10,200	\$	10,200	\$	30,700
Total Capital Cost	\$ 7,700	\$	43,500	\$	35,800	\$	35,800	\$	122,900



2020-Hess-F-8									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year				
PIPE771	8	592	Fire Flow	Hess	2020				

Canital Cast Oninian Components	Year								Total	
Capital Cost Opinion Components	20	17	2018		2019		2020	\$		
Design Cost (20%)				\$	8,900			\$	8,900	
Construction Cost				\$	22,150	\$	22,150	\$	44,300	
Contingency (40%)				\$	8,850	\$	8,850	\$	17,700	
Total Capital Cost	\$	-	\$ -	\$	39,900	\$	31,000	\$	70,900	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Kellogg Ave 167th St and Maple St to 151st St





NOT TO SCALE

2020-Hess-F-11									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year				
PIPE577	12	5241	Fire Flow	Hess	2020				

Capital Cost Opinion Components	Year									Total	
Capital Cost Opinion Components		2017		2018		2019		2020		\$	
Design Cost (20%)	\$	28,300	\$	28,300					\$	56,600	
Construction Cost			\$	94,300	\$	94,300	\$	94,300	\$	283,000	
Contingency (40%)			\$	37,700	\$	37,700	\$	37,700	\$	113,200	
Total Capital Cost	\$	28,300	\$	160,300	\$	132,000	\$	132,000	\$	452,800	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.





NOT TO SCALE

	2020-	Hess-F-12			
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE579	12	1613	Fire Flow	Hess	2020

Canital Cast Opinion Components	Year									Total
Capital Cost Opinion Components		2017		2018	2019		2020			\$
Design Cost (20%)	\$	8,700	\$	8,700					\$	17,400
Construction Cost			\$	29,000	\$	29,000	\$	29,000	\$	87,100
Contingency (40%)			\$	11,600	\$	11,600	\$	11,600	\$	34,800
Total Capital Cost	\$	8,700	\$	49,300	\$	40,600	\$	40,600	\$	139,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.





NOT TO SCALE

	2020-Hess-F-13											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE581	12	1661	Fire Flow	Hess	2020							

Canital Cast Opinion Components		Total							
Capital Cost Opinion Components	2017		2018		2019		2020		\$
Design Cost (20%)	\$ 9,000	\$	9,000					\$	17,900
Construction Cost		\$	29,900	\$	29,900	\$	29,900	\$	89,700
Contingency (40%)		\$	12,000	\$	12,000	\$	12,000	\$	35,900
Total Capital Cost	\$ 9,000	\$	50,900	\$	41,900	\$	41,900	\$	143,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.





	2020	D-Hess-F-14			
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE583	12	3612	Fire Flow	Hess	2020

Capital Cost Opinion Components			Yea	r					Total
Capital Cost Opinion Components	2017		2018		2019		2020	\$	
Design Cost (20%)	\$ 19,500		19,500					\$	39,000
Construction Cost		\$	65,000	\$	65,000	\$	65,000	\$	195,000
Contingency (40%)		\$	26,000	\$	26,000	\$	26,000	\$	78,000
Total Capital Cost	\$ 19,500	\$	110,500	\$	91,000	\$	91,000	\$	312,000

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



2020-Hess-F-15			
Diameter (in) Length (ft) Trigger	Pressure Zone	CIP Year

Hess

2020

Fire Flow

Canital Cast Oninion Components	Year								Total
Capital Cost Opinion Components	201	17	20	18	2019		2020		\$
Design Cost (20%)					\$ 12,000			\$	12,000
Construction Cost					\$ 30,100	\$	30,100	\$	60,200
Contingency (40%)					\$ 12,050	\$	12,050	\$	24,100
Total Capital Cost	\$	-	\$	-	\$ 54,150	\$	42,150	\$	96,300

536

Notes:

Model ID

PIPE775

1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)

12

- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.





NOT TO SCALE

	2020-Hess-F-11, 12, 14, 15											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE775	12	536	Fire Flow	Hess	2020							
PIPE583	12	3612	Fire Flow	Hess	2020							
PIPE579	12	1613	Fire Flow	Hess	2020							
PIPE577	12	5241	Fire Flow	Hess	2020							

Capital Cost Opinion Components	Year									Total
Capital Cost Opinion Components	2017			2018		2019		2020		\$
Design Cost (20%)	\$	56,500	\$	56,500	\$	12,000	\$	-	\$	125,000
Construction Cost	\$	-	\$	188,300	\$	218,400	\$	218,400	\$	625,300
Contingency (40%)	\$	-	\$	75,300	\$	87,350	\$	87,350	\$	250,100
Total Capital Cost	\$	56,500	\$	320,100	\$	317,750	\$	305,750	\$ 1	,000,400

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Old Lawrence Rd Between 30th St S and 31st St E



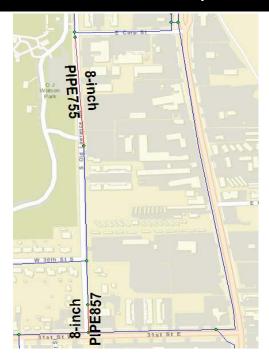


	2020-H	ess-F-18									
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE857	8	186	Fire Flow	Hess	2020						

Conital Cost Oninion Components				Υ	ear				Total	
Capital Cost Opinion Components	2	017	20)18		2019	2020	\$		
Design Cost (20%)					\$	2,800		\$	2,800	
Construction Cost							\$ 13,900	\$	13,900	
Contingency (40%)							\$ 5,600	\$	5,600	
Total Capital Cost	\$	-	\$	-	\$	2,800	\$ 19,500	\$	22,300	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Old Lawrence Rd Between Carp St and 31th St E



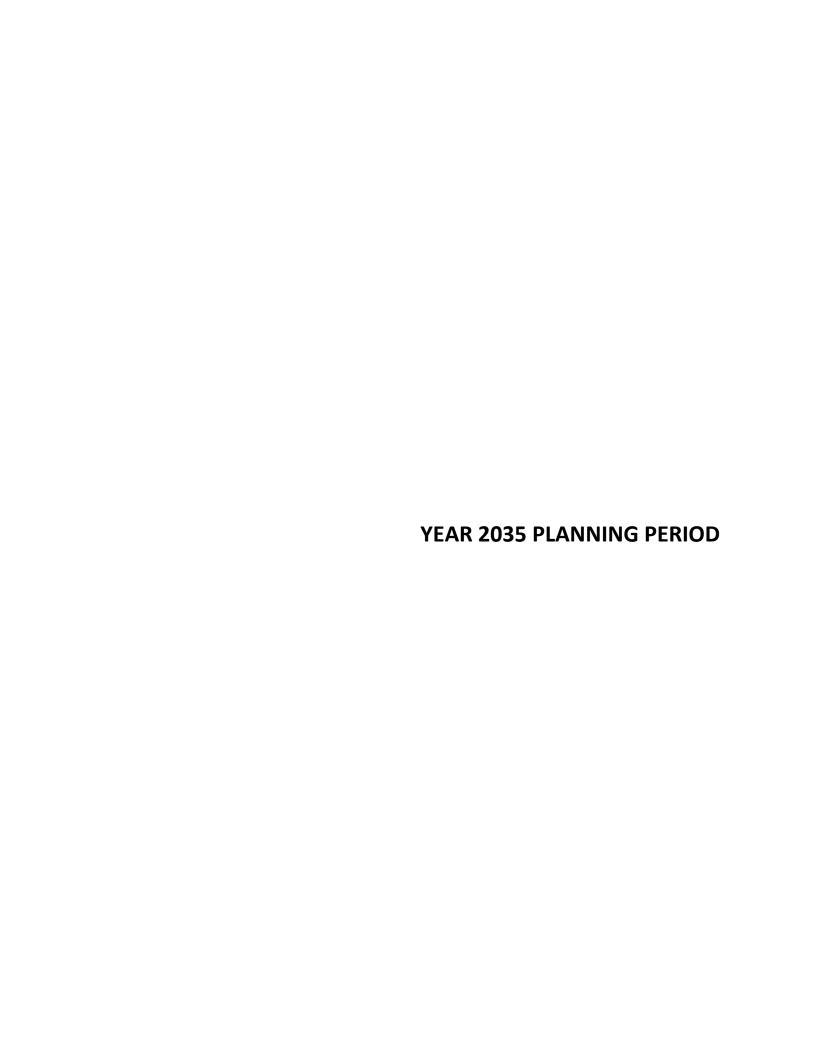


NOT TO SCALE

	2020-Hess-F-1, 18											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE755	8	731	Fire Flow	Hess	2020							
PIPE857 8 186 Fire Flow Hess 2020												

Canital Cost Oninion Components	Year								Total
Capital Cost Opinion Components	2017		2018		2019		2020		\$
Design Cost (20%)	\$ -	\$	-	\$	13,700	\$	-	\$	13,700
Construction Cost	\$ -	\$	-	\$	27,300	\$	41,200	\$	68,500
Contingency (40%)	\$ -	\$	-	\$	10,900	\$	16,500	\$	27,400
Total Capital Cost	\$ -	\$	-	\$	51,900	\$	57,700	\$	109,600

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



Corner of Sheridan St and Burton St



	2035-Hess-H-1											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE701	8	15	Hydraulic	Hess	2035							

Capital Cost Opinion	Year						Total
Components	2032		2033		2034	2035	\$
Design Cost (20%)					\$ 1,000		\$ 1,000
Construction Cost						\$ 1,100	\$ 1,100
Contingency (40%)						\$ 500	\$ 500
Total Capital Cost	\$	-	\$	-	\$ 1,000	\$ 1,600	\$ 2,600

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Sheridan St and Burton St N N PIPE 701 07

	2035 Hess-H-2											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE703	8	82	Hydraulic	Hess	2035							

NOT TO SCALE

Capital Cost Opinion		Ye	ear			Total		
Components	2032	2033		2034	2035		\$	
Design Cost (20%)			\$	1,200		\$	1,200	
Construction Cost					\$ 6,100	\$	6,100	
Contingency (40%)					\$ 2,400	\$	2,400	
Total Capital Cost	\$ -	\$ -	\$	1,200	\$ 8,500	\$	9,700	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Sheridan St and Burton St N N N PIPE 701 02

	2035 Hess-H- 1, 2											
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year												
PIPE701	8	15	Hydraulic	Hess	2035							
PIPE703	8	82	Hydraulic	Hess	2035							

NOT TO SCALE

Capital Cost Opinion	Year								
Components	2032 2033 2034 2035							\$	
Design Cost (20%)	\$ -	\$	-	\$	2,200	\$	-	\$	2,200
Construction Cost	\$ -	\$	-	\$	-	\$	7,200	\$	7,200
Contingency (40%)	\$ -	\$	-	\$	-	\$	2,900	\$	2,900
Total Capital Cost	\$ -	\$	-	\$	2,200	\$	10,100	\$	12,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Lorraine St and 17th St



NOT TO SCALE

		2035 H	ess-H-3		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE721	8	163	Hydraulic	Hess	2035

Capital Cost	Year				Total
Opinion	2032	2033	2034	2035	\$
Design Cost (20%)			\$ 2,400		\$ 2,400
Construction Cost				\$ 12,200	\$ 12,200
Contingency (40%))			\$ 4,900	\$ 4,900
Total Capital Cost	\$ -	\$ -	\$ 2,400	\$ 17,100	\$ 19,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

School St Between Acadia St and Ridge Rd



NOT TO SCALE

		2035 Hess	s-H-4		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE665	12	217	Hydraulic	Hess	2035

Capital Cost Opinion	Year								Total
Components	2032		2033	2034 2035					\$
Design Cost (20%)				\$	4,900			\$	4,900
Construction Cost						\$	24,300	\$	24,300
Contingency (40%)						\$	9,700	\$	9,700
Total Capital Cost	\$ -	\$	-	\$	4,900	\$	34,000	\$	38,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Arkansas Ave and 29th St



NOT TO SCALE

	2035 Hess-H-6									
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE711	12	62	Hydraulic	Hess	2035					

Capital Cost Opinion			Total						
Components	2032	2	2033	2034 2035			2035	\$	
Design Cost (20%)				\$	1,400			\$	1,400
Construction Cost						\$	7,000	\$	7,000
Contingency (40%)						\$	2,800	\$	2,800
Total Capital Cost	\$ -	\$	-	\$	1,400	\$	9,800	\$	11,200

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Lincoln St and Woodlawn St



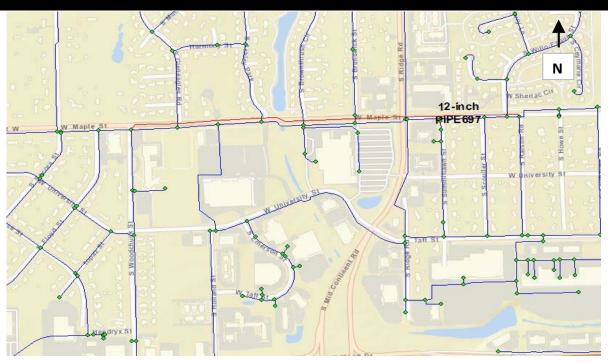
NOT TO SCALE

	2035 Hess-H-7									
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE673	16	48	Hydraulic	Hess	2035					

Capital Cost Opinion		Total				
Components	2032	2033	2034	2035	\$	
Design Cost (20%)			\$ 1,400		\$	1,400
Construction Cost				\$ 7,100	\$	7,100
Contingency (40%)				\$ 2,800	\$	2,800
Total Capital Cost	\$ -	\$ -	\$ 1,400	\$ 9,900	\$	11,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Maple St Between Woodchuck St and Ralstin Rd



NOT TO SCALE

	2035 Hess-H-8										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE697	16	3781	Hydraulic	Hess	2035						

Capital Cost Opinion	Year										
Components	2032		2033		2034		2035		\$		
Design Cost (20%)	\$ 56,600	\$	56,600					\$	113,100		
Construction Cost		\$	188,500	\$	188,500	\$	188,500	\$	565,600		
Contingency (40%)		\$	75,400	\$	75,400	\$	75,400	\$	226,200		
Total Capital Cost	\$ 56,600	\$	320,500	\$	263,900	\$	263,900	\$	904,900		

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

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2035 Hess-H-9											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE725 16 14 Hydraulic Hess 2035											

Capital Cost Opinion				Total				
Components	2	032	:	2033	2034	2035	\$	
Design Cost (20%)					\$ 1,000		\$	1,000
Construction Cost						\$ 2,100	\$	2,100
Contingency (40%)						\$ 800	\$	800
Total Capital Cost	\$	-	\$	-	\$ 1,000	\$ 2,900	\$	3,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of 21st and Ridge Rd



NOT TO SCALE

	2035 Hess-H-11										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE699	20	163	Hydraulic	Hess	2035						

Capital Cost Opinion		Year								Total	
Components	- 2	2032		2033	2	2034		2035	\$		
Design Cost (20%)					\$	6,100			\$	6,100	
Construction Cost							\$	30,400	\$	30,400	
Contingency (40%)							\$	12,200	\$	12,200	
Total Capital Cost	\$	-	\$	-	\$	6,100	\$	42,600	\$	48,700	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of Greenwich Rd and Harry St



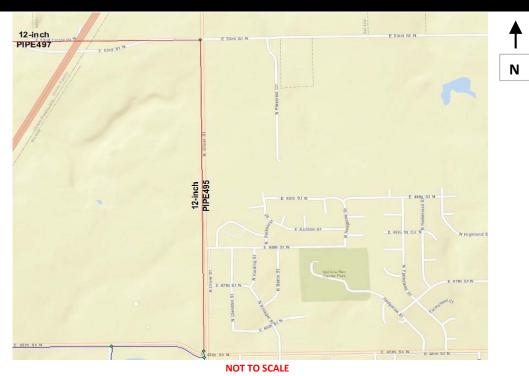
	2035 East-H-1									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year					
PIPE709	12	18	Hydraulic	East	2035					

Capital Cost Opinion	Year								
Components	2032		2033		2034		2035		\$
Design Cost (20%)				\$	1,000			\$	1,000
Construction Cost						\$	2,000	\$	2,000
Contingency (40%)						\$	800	\$	800
Total Capital Cost	\$ -	\$	-	\$	1,000	\$	2,800	\$	3,800

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



Oliver St Between 53rd St and 45th St

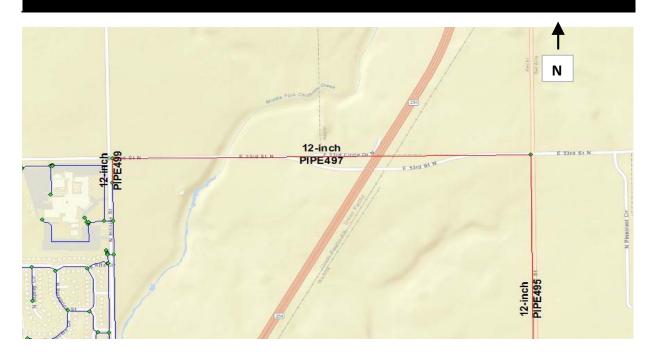


	2045-Hess-G-1										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE495	12	5436	Growth	Hess	2045						

Capital Cost Opinion		Total					
Components	2042	2043	2044		2045		\$
Design Cost (20%)	\$ 29,400	\$ 29,400					\$ 58,700
Construction Cost		\$ 97,800	\$	97,800	\$	97,800	\$ 293,500
Contingency (40%)		\$ 39,100	\$	39,100	\$	39,100	\$ 117,400
Total Capital Cost	\$ 29,400	\$ 166,300	\$	136,900	\$	136,900	\$ 469,600

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

53rd St Between Hillside St and Oliver St



NOT TO SCALE

	2045-Hess-G-2										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE497	12	5229	Growth	Hess	2045						

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 28,300	\$ 28,300			\$ 56,500
Construction Cost		\$ 94,100	\$ 94,100	\$ 94,100	\$ 282,400
Contingency (40%)		\$ 37,700	\$ 37,700	\$ 37,700	\$ 113,000
Total Capital Cost	\$ 28,300	\$ 160,100	\$ 131,800	\$ 131,800	\$ 451,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Corner of 53rd St and Hillside St



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	2045-Hess-G-3										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE499	12	333	Growth	Hess	2045						

Capital Cost Opinion		Year									
Components	2042	2043		2044		2045		\$			
Design Cost (20%)			\$	3,600			\$	3,600			
Construction Cost			\$	9,000	\$	9,000	\$	18,000			
Contingency (40%)			\$	3,600	\$	3,600	\$	7,200			
Total Capital Cost	\$ -	\$ -	\$	16,200	\$	12,600	\$	28,800			

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

61st St Between West St and Edwards St



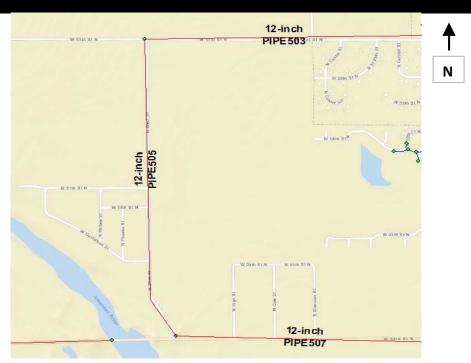
NOT TO SCALE

	2045-Hess-G-5									
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE503	1 1 5 1 1 56									

Capital Cost Opinion			Total						
Components	2042		2043		2044		2045	\$	
Design Cost (20%)	\$ 24,000	\$	24,000					\$	48,000
Construction Cost		\$	80,000	\$	80,000	\$	80,000	\$	240,000
Contingency (40%)		\$	32,000	\$	32,000	\$	32,000	\$	96,000
Total Capital Cost	\$ 24,000	\$	136,000	\$	112,000	\$	112,000	\$	384,000

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

West St Between 61st St and 53rd St



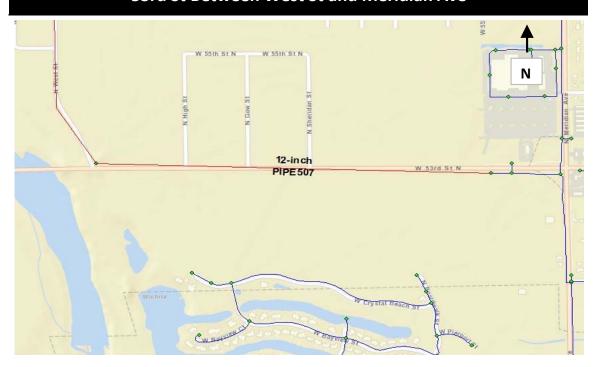
NOT TO SCALE

	2045-Hess-G-6									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year					
PIPE505	12	5375	Growth	Hess	2045					

Capital Cost Opinion			Total					
Components	2042	2043		2044		2045		\$
Design Cost (20%)	\$ 29,100	\$ 29,100					\$	58,100
Construction Cost		\$ 96,800	\$	96,800	\$	96,800	\$	290,300
Contingency (40%)		\$ 38,700	\$	38,700	\$	38,700	\$	116,100
Total Capital Cost	\$ 29,100	\$ 164,600	\$	135,500	\$	135,500	\$	464,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

53rd St Between West St and Meridian Ave



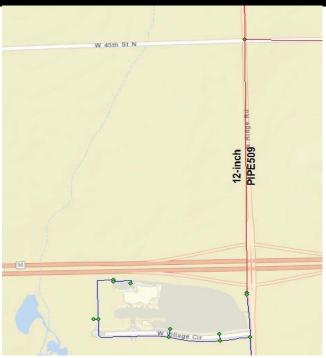
NOT TO SCALE

	2045-Hess-G-7									
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE507	() () ()									

Capital Cost Opinion		Year								Total
Components	2042			2043		2044		2045	\$	
Design Cost (20%)	\$	22,200	\$	22,200					\$	44,300
Construction Cost			\$	73,800	\$	73,800	\$	73,800	\$	221,400
Contingency (40%)			\$	29,500	\$	29,500	\$	29,500	\$	88,600
Total Capital Cost	\$	22,200	\$	125,500	\$	103,300	\$	103,300	\$	354,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Ridge Rd Between 45th St and Village Cir





NOT TO SCALE

	2045-Hess-G-8										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE509	12 2853 Growth Hess 2045										

Capital Cost Opinion			Total					
Components	2042	2043		2044	2045		\$	
Design Cost (20%)	\$ 15,400	\$	15,400				\$	30,800
Construction Cost		\$	51,400	\$ 51,400	\$	51,400	\$	154,100
Contingency (40%)		\$	20,500	\$ 20,500	\$	20,500	\$	61,600
Total Capital Cost	\$ 15,400	\$	87,300	\$ 71,900	\$	71,900	\$	246,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Ridge Rd Between 53rd St and 45th St



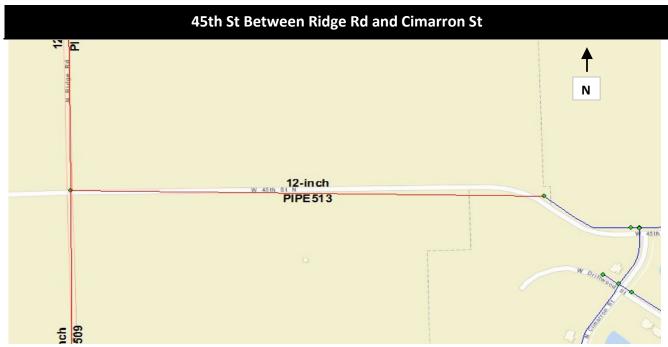


NOT TO SCALE

	2045-Hess-G-9										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE511	12	5334	Growth	Hess	2045						

Capital Cost Opinion		Total				
Components	2042 2043 2044 2045		\$			
Design Cost (20%)	\$ 28,800	\$	28,800			\$ 57,600
Construction Cost		\$	96,000	\$ 96,000	\$ 96,000	\$ 288,000
Contingency (40%)		\$	38,400	\$ 38,400	\$ 38,400	\$ 115,200
Total Capital Cost	\$ 28,800	\$	163,200	\$ 134,400	\$ 134,400	\$ 460,800

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

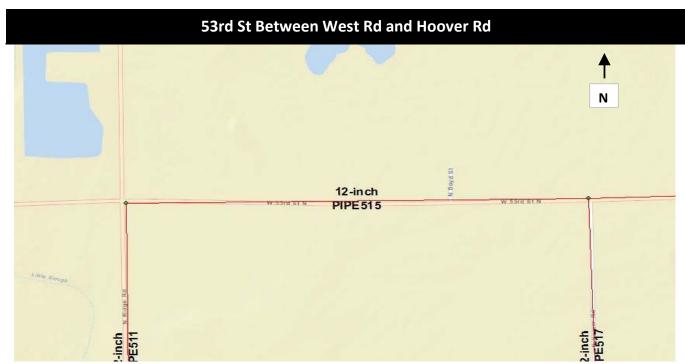


NOT TO SCALE

2045-Hess-G-10									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year				
PIPE513	12	2653	Growth	Hess	2045				

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 14,400	\$ 14,400			\$ 28,700
Construction Cost		\$ 47,800	\$ 47,800	\$ 47,800	\$ 143,300
Contingency (40%)		\$ 19,100	\$ 19,100	\$ 19,100	\$ 57,300
Total Capital Cost	\$ 14,400	\$ 81,300	\$ 66,900	\$ 66,900	\$ 229,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



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	2045-Hess-G-11										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE515	12	5205	Growth	Hess	2045						

Capital Cost Opinion	Year								Total
Components	2042		2043		2044		2045		\$
Design Cost (20%)	\$ 28,100	\$	28,100					\$	56,200
Construction Cost		\$	93,700	\$	93,700	\$	93,700	\$	281,000
Contingency (40%)		\$	37,500	\$	37,500	\$	37,500	\$	112,400
Total Capital Cost	\$ 28,100	\$	159,300	\$	131,200	\$	131,200	\$	449,600

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Hoover Rd Between 53rd St and 45th St



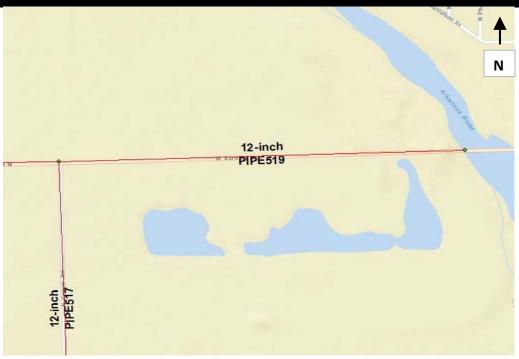
NOT TO SCALE

	2045-Hess-G-12										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE517	12	5577	Growth	Hess	2045						

Capital Cost Opinion			,	Year				Total	
Components	2042	2043			2044	2045	\$		
Design Cost (20%)	\$ 30,100	\$	30,100				\$	60,200	
Construction Cost		\$	100,400	\$	100,400	\$ 100,400	\$	301,200	
Contingency (40%)		\$	40,200	\$	40,200	\$ 40,200	\$	120,500	
Total Capital Cost	\$ 30,100	\$	170,700	\$	140,600	\$ 140,600	\$	481,900	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

53rd St Between Hoover Rd and the Arkansas River



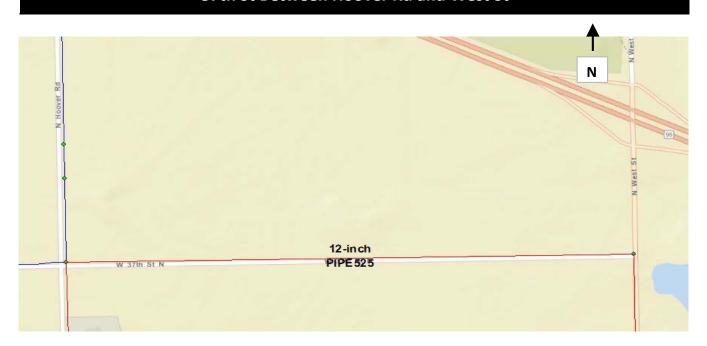
NOT TO SCALE

		2045-Hess-	G-13		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE519	8	4690	Growth	Hess	2045

Capital Cost Opinion			Total				
Components	2042	2043	2044		2045		\$
Design Cost (20%)	\$ 16,900	\$ 16,900				\$	33,800
Construction Cost		\$ 56,300	\$ 56,300	\$	56,300	\$	168,800
Contingency (40%)		\$ 22,500	\$ 22,500	\$	22,500	\$	67,500
Total Capital Cost	\$ 16,900	\$ 95,700	\$ 78,800	\$	78,800	\$	270,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

37th St Between Hoover Rd and West St



NOT TO SCALE

		2045-Hes	s-G-14		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE525	12	5248	Growth	Hess	2045

Capital Cost Opinion				Total				
Components	2042	2043	2044		2045	\$		
Design Cost (20%)	\$ 28,400	\$ 28,400				\$	56,700	
Construction Cost		\$ 94,500	\$ 94,500	\$	94,500	\$	283,400	
Contingency (40%)		\$ 37,800	\$ 37,800	\$	37,800	\$	113,400	
Total Capital Cost	\$ 28,400	\$ 160,700	\$ 132,300	\$	132,300	\$	453,500	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Hoover Rd Between 37th St and 39th St N Glida St N Glida St N Hoover Rd PIPE527 PIPE527

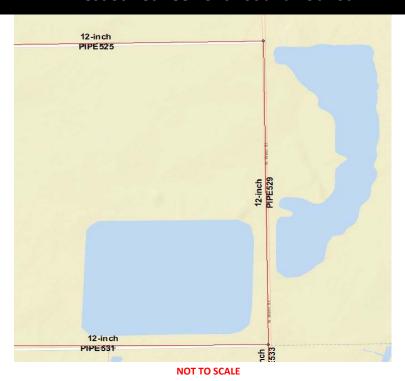
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	2045-Hess-G-15										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE527	12	5242	Growth	Hess	2045						

Capital Cost Opinion			Total							
Components	2042 2043 2044 2045					2045		\$		
Design Cost (20%)	\$	28,300	\$	28,300					\$	56,600
Construction Cost			\$	94,400	\$	94,400	\$	94,400	\$	283,100
Contingency (40%)			\$	37,700	\$	37,700	\$	37,700	\$	113,200
Total Capital Cost	\$	28,300	\$	160,400	\$	132,100	\$	132,100	\$	452,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

West St Between 37th St and 29th St





		2045-He	ss-G-16		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE529	12	5292	Growth	Hess	2045

Capital Cost Opinion			Ye	ar	Year										
Components	2042	2043		2044	2045			\$							
Design Cost (20%)	\$ 28,600	\$ 28,600					\$	57,200							
Construction Cost		\$ 95,300	\$	95,300	\$	95,300	\$	285,800							
Contingency (40%)		\$ 38,100	\$	38,100	\$	38,100	\$	114,300							
Total Capital Cost	\$ 28,600	\$ 162,000	\$	133,400	\$	133,400	\$	457,300							

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

29th St Between Hoover Rd and West St N 12-inch PIPE 531 Qui-ZI Q

		2045-Hess-G-17										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE531	12	5187	Growth	Hess	2045							

NOT TO SCALE

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 28,000	\$ 28,000				\$ 56,000
Construction Cost		\$ 93,400	\$ 93,400	\$	93,400	\$ 280,100
Contingency (40%)		\$ 37,300	\$ 37,300	\$	37,300	\$ 112,000
Total Capital Cost	\$ 28,000	\$ 158,700	\$ 130,700	\$	130,700	\$ 448,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

West St Between 29th St and Bayside St 12-inch N West St PIPE533 N West St

NOT TO SCALE

	2045-Hess-G-18										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE533	12	1359	Growth	Hess	2045						

Capital Cost Opinion				Year			Total		
Components	2042			2043	2044	2045		\$	
Design Cost (20%)	\$	7,400	\$	7,400			\$	14,700	
Construction Cost			\$	24,500	\$ 24,500	\$ 24,500	\$	73,400	
Contingency (40%)			\$	9,800	\$ 9,800	\$ 9,800	\$	29,400	
Total Capital Cost	\$	7,400	\$	41,700	\$ 34,300	\$ 34,300	\$	117,500	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

NOT TO SCALE

		2045-Hess-0	G-19		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE537	12	1594	Growth	Hess	2045

Capital Cost Opinion			Υe	ar				Total		
Components	2042		2043		2044		2045		\$	
Design Cost (20%)	\$	8,600	\$ 8,600					\$	17,200	
Construction Cost			\$ 28,700	\$	28,700	\$	28,700	\$	86,100	
Contingency (40%)			\$ 11,500	\$	11,500	\$	11,500	\$	34,400	
Total Capital Cost	\$	8,600	\$ 48,800	\$	40,200	\$	40,200	\$	137,700	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Ridge Rd Off of Southwest Blvd





NOT TO SCALE

		2045-Hess-0	G-21		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE541	16	1437	Growth	Hess	2045

Capital Cost Opinion			Yea	r				Total	
Components	2042	2043		2044		2045		\$	
Design Cost (20%)	\$ 10,400	\$ 10,400					\$	20,700	
Construction Cost		\$ 34,500	\$	34,500	\$	34,500	\$	103,400	
Contingency (40%)		\$ 13,800	\$	13,800	\$	13,800	\$	41,400	
Total Capital Cost	\$ 10,400	\$ 58,700	\$	48,300	\$	48,300	\$	165,500	

- CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

MacArthur Rd Between Maize Rd and Norman St 12-inch PIPE547 W MacArthur Rd S

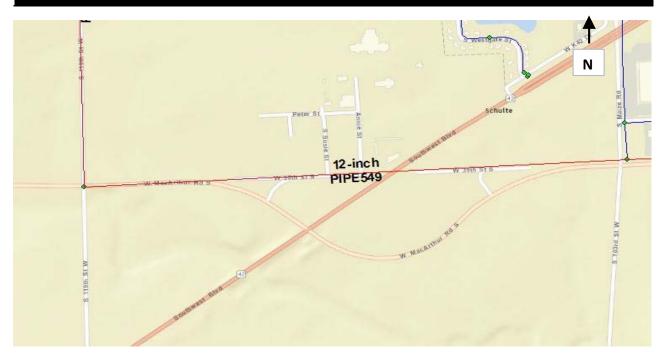
NOT TO SCALE

		2045 -Hess-G	i-22		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE547	12	2008	Growth	Hess	2045

Capital Cost Opinion			Υe	ear					Total	
Components	2042		2043		2044		2045		\$	
Design Cost (20%)	\$ 10,900	\$	10,900					\$	21,700	
Construction Cost		\$	36,100	\$	36,100	\$	36,100	\$	108,400	
Contingency (40%)		\$	14,500	\$	14,500	\$	14,500	\$	43,400	
Total Capital Cost	\$ 10,900	\$	61,500	\$	50,600	\$	50,600	\$	173,500	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

39th St Between 119th St and Maize Rd



NOT TO SCALE

		2045-Hess-G-2	23		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE549	12	5597	Growth	Hess	2045

Capital Cost Opinion		Year									
Components	2042			2043		2044		2045		\$	
Design Cost (20%)	\$	30,200	\$	30,200					\$	60,400	
Construction Cost			\$	100,700	\$	100,700	\$	100,700	\$	302,200	
Contingency (40%)			\$	40,300	\$	40,300	\$	40,300	\$	120,900	
Total Capital Cost	\$	30,200	\$	171,200	\$	141,000	\$	141,000	\$	483,500	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

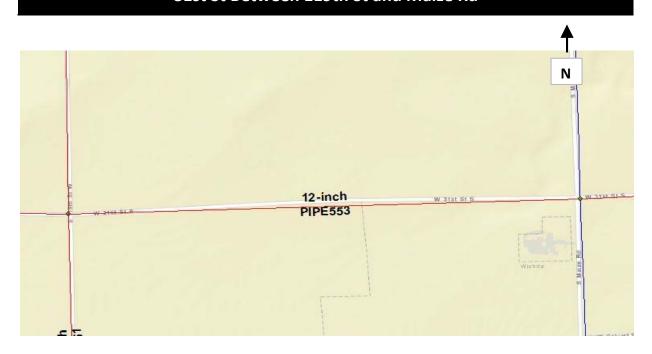
NOT TO SCALE

	2	2045-Hess-	G-24		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE551	12	5305	Growth	Hess	2045

Capital Cost Opinion			Υ	'ear					Total
Components	2042	2043		2044		2045		\$	
Design Cost (20%)	\$ 28,700	\$	28,700					\$	57,300
Construction Cost		\$	95,500	\$	95,500	\$	95,500	\$	286,500
Contingency (40%)		\$	38,200	\$	38,200	\$	38,200	\$	114,600
Total Capital Cost	\$ 28,700	\$	162,400	\$	133,700	\$	133,700	\$	458,400

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

31st St Between 119th St and Maize Rd



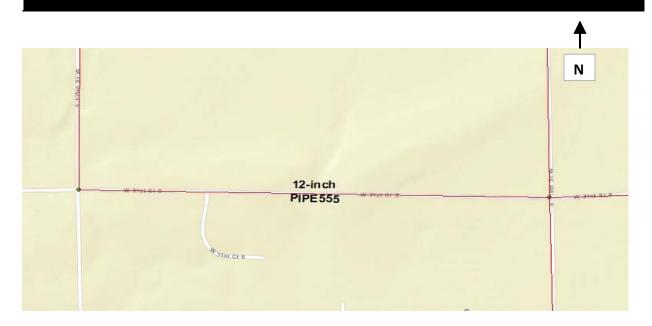
NOT TO SCALE

	2045-Hess-G-25										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE553	12	5535	Growth	Hess	2045						

Capital Cost Opinion		Total				
Components	2042	2043	2044	2045		\$
Design Cost (20%)	\$ 29,900	\$ 29,900			\$	59,800
Construction Cost		\$ 99,600	\$ 99,600	\$ 99,600	\$	298,900
Contingency (40%)		\$ 39,900	\$ 39,900	\$ 39,900	\$	119,600
Total Capital Cost	\$ 29,900	\$ 169,400	\$ 139,500	\$ 139,500	\$	478,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

31st St Between 135th St and 119th St



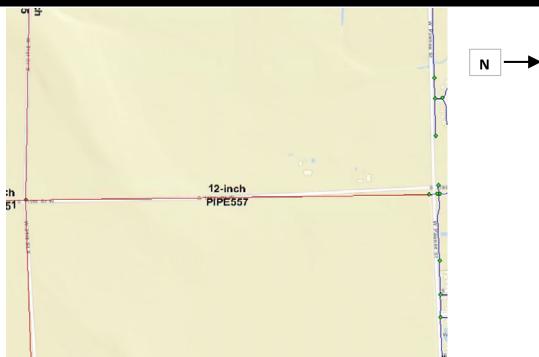
NOT TO SCALE

	2045-Hess-G-26										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE555*	12	5261	Growth	Hess	2045						

Capital Cost Opinion		Total				
Components	2042	2043	2044	2045		\$
Design Cost (20%)	\$ 28,400	\$ 28,400			\$	56,800
Construction Cost		\$ 94,700	\$ 94,700	\$ 94,700	\$	284,100
Contingency (40%)		\$ 37,900	\$ 37,900	\$ 37,900	\$	113,600
Total Capital Cost	\$ 28,400	\$ 161,000	\$ 132,600	\$ 132,600	\$	454,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

119th St Between Pawnee St and 31st St



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	2045-Hess-G-27										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE557	12	5205	Growth	Hess	2045						

Capital Cost Opinion		Total						
Components	2042	2043 2044		2045		\$		
Design Cost (20%)	\$ 28,100	\$	28,100					\$ 56,200
Construction Cost		\$	93,700	\$	93,700	\$	93,700	\$ 281,100
Contingency (40%)		\$	37,500	\$	37,500	\$	37,500	\$ 112,400
Total Capital Cost	\$ 28,100	\$	159,300	\$	131,200	\$	131,200	\$ 449,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

135th St Between Pawnee St and 31st St



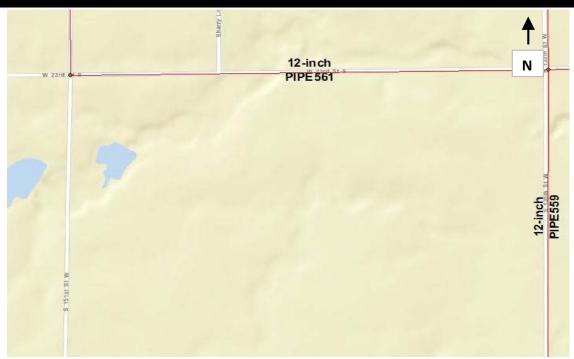
NOT TO SCALE

	2045-Hess-G-28											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE559*	12	5035	Growth	Hess	2045							

Capital Cost Opinion			Total							
Components	2042 2043		2043		2044		2045	\$		
Design Cost (20%)	\$ 27,200	\$	27,200					\$	54,400	
Construction Cost		\$	90,600	\$	90,600	\$	90,600	\$	271,900	
Contingency (40%)		\$	36,300	\$	36,300	\$	36,300	\$	108,800	
Total Capital Cost	\$ 27,200	\$	154,100	\$	126,900	\$	126,900	\$	435,100	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

23rd St Between 151st St and 135th St



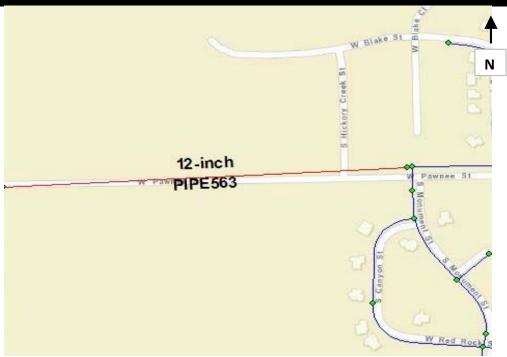
NOT TO SCALE

	2045-Hess-G-29											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE561	12	5296	Growth	Hess	2045							

Capital Cost Opinion				Total						
Components	2042			2043		2044		2045	\$	
Design Cost (20%)	\$	28,600	\$	28,600					\$	57,200
Construction Cost			\$	95,300	\$	95,300	\$	95,300	\$	286,000
Contingency (40%)			\$	38,100	\$	38,100	\$	38,100	\$	114,400
Total Capital Cost	\$	28,600	\$	162,000	\$	133,400	\$	133,400	\$	457,600

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Pawnee St Between 135th St and Monument St



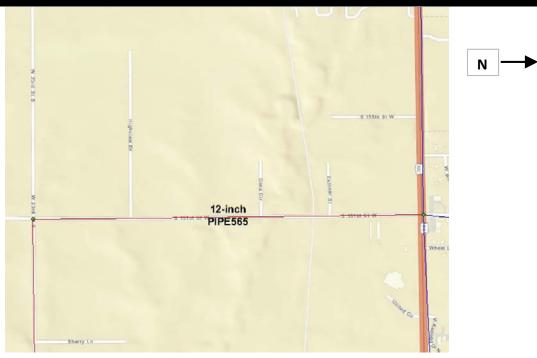
NOT TO SCALE

	2045-Hess-G-30										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE563	12	1690	Growth	Hess	2045						

Capital Cost Opinion		Υe	ar			Total	
Components	2042	2043		2044	2045		\$
Design Cost (20%)	\$ 9,200	\$ 9,200				\$	18,300
Construction Cost		\$ 30,400	\$	30,400	\$ 30,400	\$	91,300
Contingency (40%)		\$ 12,200	\$	12,200	\$ 12,200	\$	36,500
Total Capital Cost	\$ 9,200	\$ 51,800	\$	42,600	\$ 42,600	\$	146,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151st St Between 23rd St and Kellogg Ave



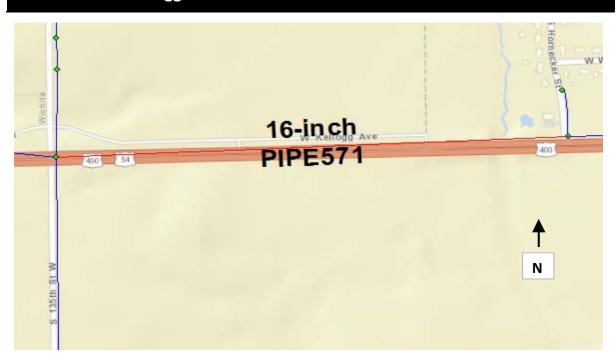
NOT TO SCALE

		2045-Hess-G	i-31							
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE565	12	5259	Growth	Hess	2045					

Capital Cost Opinion		Ye	ar			Total
Components	2042	2043		2044	2045	\$
Design Cost (20%)	\$ 28,400	\$ 28,400				\$ 56,800
Construction Cost		\$ 94,700	\$	94,700	\$ 94,700	\$ 284,000
Contingency (40%)		\$ 37,900	\$	37,900	\$ 37,900	\$ 113,600
Total Capital Cost	\$ 28,400	\$ 161,000	\$	132,600	\$ 132,600	\$ 454,400

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Kellogg Ave Between 135th St and Hornecker St



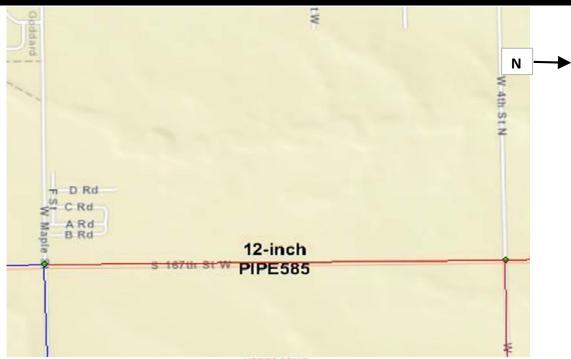
NOT TO SCALE

	2045-Hess-G-34										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE571	16	3572	Growth	Hess	2045						

Capital Cost Opinion		Υe	ar			Total
Components	2042	2043		2044	2045	\$
Design Cost (20%)	\$ 25,700	\$ 25,700				\$ 51,400
Construction Cost		\$ 85,700	\$	85,700	\$ 85,700	\$ 257,200
Contingency (40%)		\$ 34,300	\$	34,300	\$ 34,300	\$ 102,900
Total Capital Cost	\$ 25,700	\$ 145,700	\$	120,000	\$ 120,000	\$ 411,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

167th St Between 4th St and Maple St



NOT TO SCALE

	2	.045-Hess-G	i-37							
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE585*	12	5292	Growth	Hess	2045					

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 28,600	\$ 28,600				\$ 57,200
Construction Cost		\$ 95,300	\$ 95,300	\$	95,300	\$ 285,800
Contingency (40%)		\$ 38,100	\$ 38,100	\$	38,100	\$ 114,300
Total Capital Cost	\$ 28,600	\$ 162,000	\$ 133,400	\$	133,400	\$ 457,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Central St Between 151st St and 167th St | Section 2015 | 12-inch | 12-inch

NOT TO SCALE

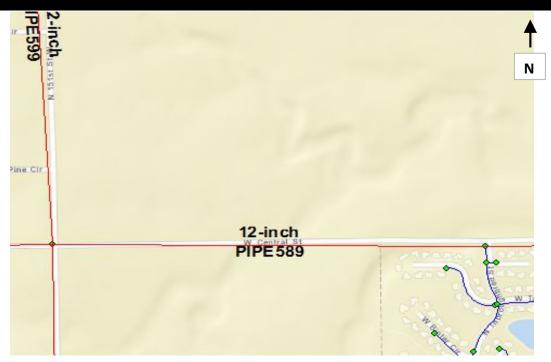
12-inch PIPE633

	2045-Hess-G-38										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE587*	12	5237	Growth	Hess	2045						

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 28,300	\$ 28,300			\$ 56,600
Construction Cost		\$ 94,300	\$ 94,300	\$ 94,300	\$ 282,800
Contingency (40%)		\$ 37,700	\$ 37,700	\$ 37,700	\$ 113,100
Total Capital Cost	\$ 28,300	\$ 160,300	\$ 132,000	\$ 132,000	\$ 452,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Central St Between 151st St and Thoroughbred St



NOT TO SCALE

	2045-Hess-G-39										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE589	12	3469	Growth	Hess	2045						

Capital Cost Opinion			Ye	ar				Total	
Components	2042	2043			2044	2045			\$
Design Cost (20%)	\$ 18,800	\$	18,800					\$	37,500
Construction Cost		\$	62,400	\$	62,400	\$	62,400	\$	187,300
Contingency (40%)		\$	25,000	\$	25,000	\$	25,000	\$	74,900
Total Capital Cost	\$ 18,800	\$	106,200	\$	87,400	\$	87,400	\$	299,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Central St Between Thoroughbred St and 135th St



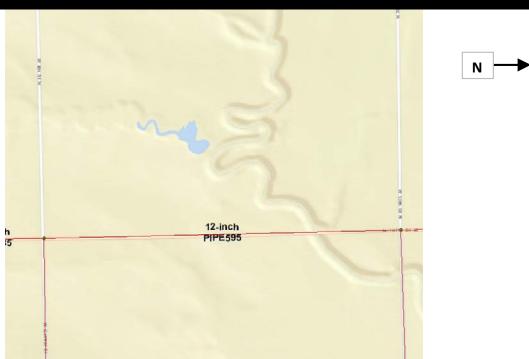
NOT TO SCALE

		2045-Hess-G	i-41							
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE593	12	1489	Growth	Hess	2045					

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 8,100	\$ 8,100			\$ 16,100
Construction Cost		\$ 26,800	\$ 26,800	\$ 26,800	\$ 80,400
Contingency (40%)		\$ 10,700	\$ 10,700	\$ 10,700	\$ 32,200
Total Capital Cost	\$ 8,100	\$ 45,600	\$ 37,500	\$ 37,500	\$ 128,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

167th St Between 13th St and 4th St



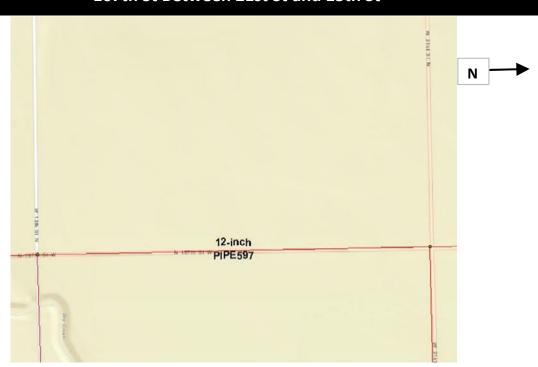
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	2	2045-Hess-G	-42		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE595*	12	5118	Growth	Hess	2045

Capital Cost Opinion	Year								Total
Components	2042		2043		2044		2045		\$
Design Cost (20%)	\$ 27,700	\$	27,700					\$	55,300
Construction Cost		\$	92,100	\$	92,100	\$	92,100	\$	276,400
Contingency (40%)		\$	36,900	\$	36,900	\$	36,900	\$	110,600
Total Capital Cost	\$ 27,700	\$	156,700	\$	129,000	\$	129,000	\$	442,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

167th St Between 21st St and 13th St



NOT TO SCALE

		2045-Hess	-G-43		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE597	12	5251	Growth	Hess	2045

Capital Cost Opinion		Total						
Components	2042	2043	2044		2045			\$
Design Cost (20%)	\$ 28,400	\$ 28,400					\$	56,700
Construction Cost		\$ 94,500	\$	94,500	\$	94,500	\$	283,600
Contingency (40%)		\$ 37,800	\$	37,800	\$	37,800	\$	113,400
Total Capital Cost	\$ 28,400	\$ 160,700	\$	132,300	\$	132,300	\$	453,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151st St Between 13th St and Central St N 12-inch PIPE599 12-inch PIPE599 13th St and Central St

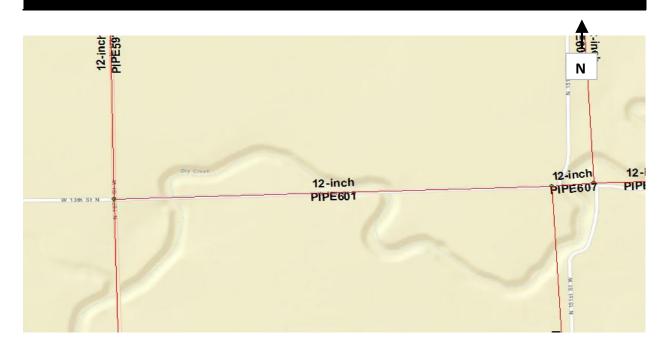
NOT TO SCALE

	2045-Hess-G-44										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE599	12	5209	Growth	Hess	2045						

Capital Cost Opinion		Υe	ar				Total
Components	2042	2043	2044		2045		\$
Design Cost (20%)	\$ 28,200	\$ 28,200				\$	56,300
Construction Cost		\$ 93,800	\$	93,800	\$ 93,800	\$	281,300
Contingency (40%)		\$ 37,500	\$	37,500	\$ 37,500	\$	112,500
Total Capital Cost	\$ 28,200	\$ 159,500	\$	131,300	\$ 131,300	\$	450,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

13th St Between 167th St and 151st St



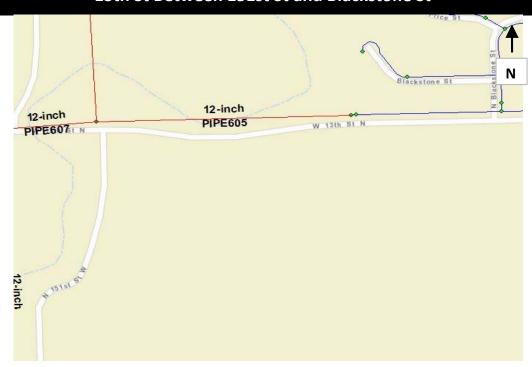
NOT TO SCALE

	2045-Hess-G-45									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year					
PIPE601	12	5065	Growth	Hess	2045					

Capital Cost Opinion		Yea	ar			Total		
Components	2042	2043		2044	2045		\$	
Design Cost (20%)	\$ 27,400	\$ 27,400				\$	54,700	
Construction Cost		\$ 91,200	\$	91,200	\$ 91,200	\$	273,500	
Contingency (40%)		\$ 36,500	\$	36,500	\$ 36,500	\$	109,400	
Total Capital Cost	\$ 27,400	\$ 155,100	\$	127,700	\$ 127,700	\$	437,600	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

13th St Between 151st St and Blackstone St



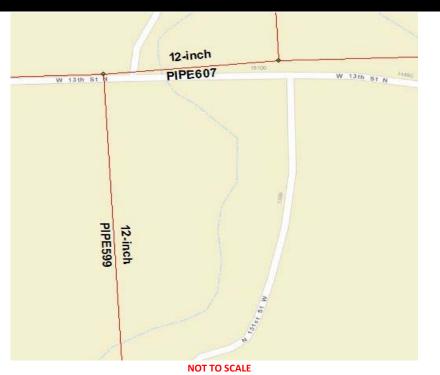
NOT TO SCALE

		2045-Hess-C	G-46		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE605	12	1231	Growth	Hess	2045

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 6,700	\$ 6,700			\$ 13,300
Construction Cost		\$ 22,200	\$ 22,200	\$ 22,200	\$ 66,500
Contingency (40%)		\$ 8,900	\$ 8,900	\$ 8,900	\$ 26,600
Total Capital Cost	\$ 6,700	\$ 37,800	\$ 31,100	\$ 31,100	\$ 106,400

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

13th St Between N 151st St and S 151st St

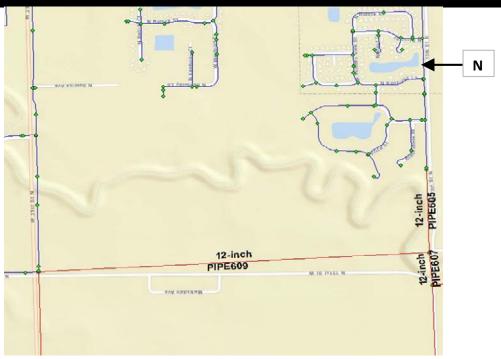


2045-Hess-G-47											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE607	12	481	Growth	Hess	2045						

Capital Cost Opinion		Year									
Components	20	42	- 2	2043		2044	2045			\$	
Design Cost (20%)					\$	82,100			\$	82,100	
Construction Cost					\$	205,350	\$	205,350	\$	410,700	
Contingency (40%)					\$	82,150	\$	82,150	\$	164,300	
Total Capital Cost	\$	-	\$	-	\$	369,600	\$	287,500	\$	657,100	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151st St Between 21st St and 13th St



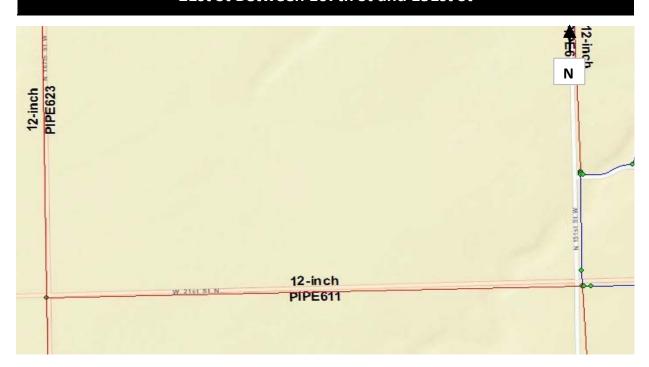
NOT TO SCALE

2045-Hess-G-48											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE609	12	5177	Growth	Hess	2045						

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 28,000	\$ 28,000			\$ 55,900
Construction Cost		\$ 93,200	\$ 93,200	\$ 93,200	\$ 279,600
Contingency (40%)		\$ 37,300	\$ 37,300	\$ 37,300	\$ 111,800
Total Capital Cost	\$ 28,000	\$ 158,500	\$ 130,500	\$ 130,500	\$ 447,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

21st St Between 167th St and 151st St



NOT TO SCALE

2045-Hess-G-49											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE611*	12	5363	Growth	Hess	2045						

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 29,000	\$ 29,000				\$ 57,900
Construction Cost		\$ 96,500	\$ 96,500	\$	96,500	\$ 289,600
Contingency (40%)		\$ 38,600	\$ 38,600	\$	38,600	\$ 115,800
Total Capital Cost	\$ 29,000	\$ 164,100	\$ 135,100	\$	135,100	\$ 463,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

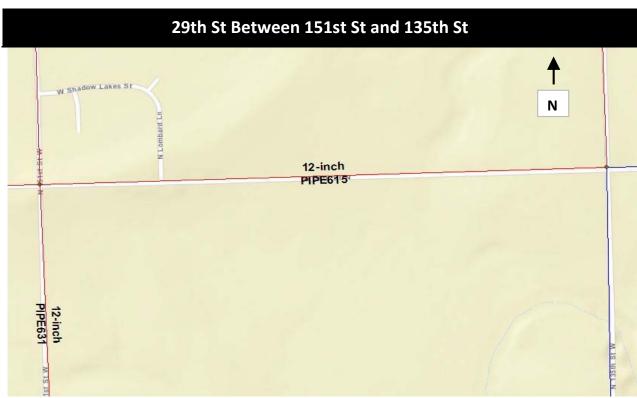
12-inch PIPE613 12-inch PIPE613 12-inch PIPE813

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2045-Hess-G-50										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE613	12	5223	Growth	Hess	2045					

Capital Cost Opinion		Total			
Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 28,200	\$ 28,200			\$ 56,400
Construction Cost		\$ 94,000	\$ 94,000	\$ 94,000	\$ 282,000
Contingency (40%)		\$ 37,600	\$ 37,600	\$ 37,600	\$ 112,800
Total Capital Cost	\$ 28,200	\$ 159,800	\$ 131,600	\$ 131,600	\$ 451,200

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



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2045-Hess-G-51											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE615	12	5250	Growth	Hess	2045						

Capital Cost Opinion		Total						
Components	2042	2043		2044		2045		\$
Design Cost (20%)	\$ 28,400	\$	28,400					\$ 56,700
Construction Cost		\$	94,500	\$	94,500	\$	94,500	\$ 283,500
Contingency (40%)		\$	37,800	\$	37,800	\$	37,800	\$ 113,400
Total Capital Cost	\$ 28,400	\$	160,700	\$	132,300	\$	132,300	\$ 453,600

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151st St Between 37th St and 29th St



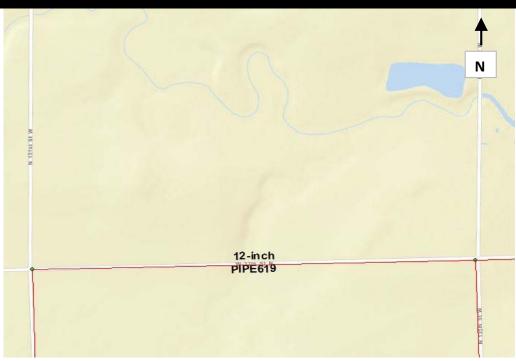
NOT TO SCALE

		2045-Hess-G	G-52						
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year								
PIPE617	12	5273	Growth	Hess	2045				

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 28,500	\$ 28,500				\$ 56,900
Construction Cost		\$ 94,900	\$ 94,900	\$	94,900	\$ 284,700
Contingency (40%)		\$ 38,000	\$ 38,000	\$	38,000	\$ 113,900
Total Capital Cost	\$ 28,500	\$ 161,400	\$ 132,900	\$	132,900	\$ 455,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

37th St Between 151st St and 135th St



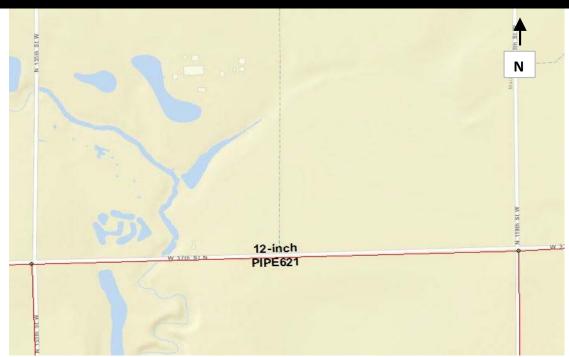
NOT TO SCALE

		2045-Hess	-G-53		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE619	12	5231	Growth	Hess	2045

Capital Cost Opinion			Total					
Components	2042	042 2043 2044 2045		2045		\$		
Design Cost (20%)	\$ 28,300	\$	28,300				\$	56,500
Construction Cost		\$	94,200	\$ 94,200	\$	94,200	\$	282,500
Contingency (40%)		\$	37,700	\$ 37,700	\$	37,700	\$	113,000
Total Capital Cost	\$ 28,300	\$	160,200	\$ 131,900	\$	131,900	\$	452,000

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

37th St Between 135th St and 119th St



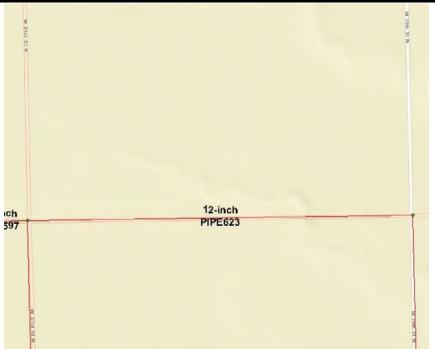
NOT TO SCALE

		2045-Hess-0	G-54						
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year								
PIPE621	12	5419	Growth	Hess	2045				

Capital Cost Opinion			Total						
Components	2042	2043		2044		2045		\$	
Design Cost (20%)	\$ 29,000	\$ 29,000					\$	58,500	
Construction Cost		\$ 98,000	\$	98,000	\$	98,000	\$	292,600	
Contingency (40%)		\$ 39,000	\$	39,000	\$	39,000	\$	117,000	
Total Capital Cost	\$ 29,000	\$ 166,000	\$	137,000	\$	137,000	\$	468,100	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

167th St Between 29th St and 21st St





NOT TO SCALE

	2045-Hess-G-55									
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE623*	12	5323	Growth	Hess	2045					

Capital Cost Opinion	Year								Total		
Components	2042		2043		2044		2045		\$		
Design Cost (20%)	\$ 28,800	\$	28,800					\$	57,500		
Construction Cost		\$	95,800	\$	95,800	\$	95,800	\$	287,400		
Contingency (40%)		\$	38,300	\$	38,300	\$	38,300	\$	115,000		
Total Capital Cost	\$ 28,800	\$	162,900	\$	134,100	\$	134,100	\$	459,900		

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

29th St Between 167th St and 151st St 12-inch PIPE625 NOT TO SCALE

	2045-Hess-G-56									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year					
PIPE625*	12	5272	Growth	Hess	2045					

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 28,500	\$ 28,500				\$ 56,900
Construction Cost		\$ 94,900	\$ 94,900	\$	94,900	\$ 284,700
Contingency (40%)		\$ 38,000	\$ 38,000	\$	38,000	\$ 113,900
Total Capital Cost	\$ 28,500	\$ 161,400	\$ 132,900	\$	132,900	\$ 455,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

37th St Between 119th St and Rutgers St



NOT TO SCALE

		2045-Hess	s-G-57						
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year								
PIPE627	12	2537	Growth	Hess	2045				

Capital Cost Opinion			Total						
Components	2042	2043		2044		2045		\$	
Design Cost (20%)	\$ 13,700	\$	13,700					\$	27,400
Construction Cost		\$	45,700	\$	45,700	\$	45,700	\$	137,000
Contingency (40%)		\$	18,300	\$	18,300	\$	18,300	\$	54,800
Total Capital Cost	\$ 13,700	\$	77,700	\$	64,000	\$	64,000	\$	219,200

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

119th St Between 37th St and 29th St





2045-Hess-G-58									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year				
PIPE629	12	5281	Growth	Hess	2045				

Capital Cost Opinion	Year								
Components	2042		2043	2044		2045			\$
Design Cost (20%)	\$ 28,500	\$	28,500					\$	57,000
Construction Cost		\$	95,100	\$	95,100	\$	95,100	\$	285,200
Contingency (40%)		\$	38,000	\$	38,000	\$	38,000	\$	114,100
Total Capital Cost	\$ 28,500	\$	161,600	\$	133,100	\$	133,100	\$	456,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151st St Between 29th St and Saint Teresa St



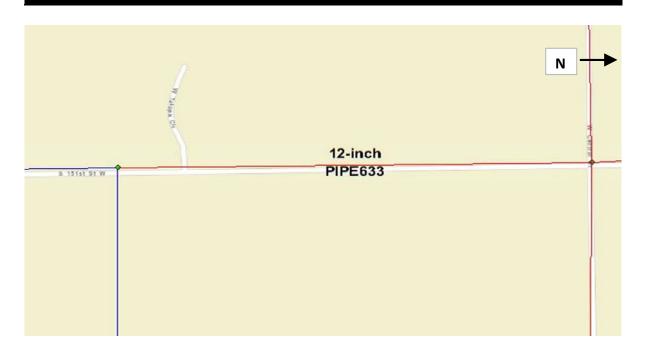
NOT TO SCALE

2045-Hess-G-59									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year				
PIPE631	12	4047	Growth	Hess	2045				

Capital Cost Opinion	Year								
Components	2042		2043		2044		2045		\$
Design Cost (20%)	\$ 21,900	\$	21,900					\$	43,700
Construction Cost		\$	72,900	\$	72,900	\$	72,900	\$	218,600
Contingency (40%)		\$	29,100	\$	29,100	\$	29,100	\$	87,400
Total Capital Cost	\$ 21,900	\$	123,900	\$	102,000	\$	102,000	\$	349,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151st St Between Central St and Talopa Cir



NOT TO SCALE

	2045-Hess-G-60											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE633	12	2631	Growth	Hess	2045							

Capital Cost Opinion		Total							
Components	2042	2043		2044		2045		\$	
Design Cost (20%)	\$ 14,200	\$	14,200					\$	28,400
Construction Cost		\$	47,400	\$	47,400	\$	47,400	\$	142,100
Contingency (40%)		\$	18,900	\$	18,900	\$	18,900	\$	56,800
Total Capital Cost	\$ 14,200	\$	80,500	\$	66,300	\$	66,300	\$	227,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

135th St to Pawnee St





NOT TO SCALE

	2045-Hess-G-61											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE799	12	2720	Growth	Hess	2045							

Capital Cost Opinion		Total					
Components	2042	2043	2044		2045		\$
Design Cost (20%)	\$ 14,700	\$ 14,700					\$ 29,400
Construction Cost		\$ 49,000	\$	49,000	\$	49,000	\$ 146,900
Contingency (40%)		\$ 19,600	\$	19,600	\$	19,600	\$ 58,800
Total Capital Cost	\$ 14,700	\$ 83,300	\$	68,600	\$	68,600	\$ 235,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering
 Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

31st St Between Maize Rd and Tyler Rd



NOT TO SCALE

	2045-Hess-G-63											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year											
PIPE639	12	3181	Growth	Hess	2045							

Capital Cost Opinion		Ye	ar					Total	
Components	2042	2043		2044		2045		\$	
Design Cost (20%)	\$ 17,200	\$ 17,200					\$	34,400	
Construction Cost		\$ 57,300	\$	57,300	\$	57,300	\$	171,800	
Contingency (40%)		\$ 22,900	\$	22,900	\$	22,900	\$	68,700	
Total Capital Cost	\$ 17,200	\$ 97,400	\$	80,200	\$	80,200	\$	274,900	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

151St Between Maple St and Talopa Cir





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	2045-Hess-G-65											
Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year												
PIPE777	12	2619	Growth	Hess	2045							

Capital Cost Opinion Components		Total			
Capital Cost Opinion Components	2042	2043	2044	2045	\$
Design Cost (20%)	\$ 29,400	\$ 29,400			\$ 58,800
Construction Cost		\$ 97,900	\$ 97,900	\$ 97,900	\$ 293,800
Contingency (40%)		\$ 39,200	\$ 39,200	\$ 39,200	\$ 117,500
Total Capital Cost	\$ 29,400	\$ 166,500	\$ 137,100	\$ 137,100	\$ 470,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

E Pawnee St between S 127th St E and S Ironstone St



NOT TO SCALE

	2045-Hess-G-66											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE777	12	3498	Growth	Hess	2045							

Capital Cost Opinion Components				Total				
Capital Cost Opinion Components		2042		2043	2044	2045		\$
Design Cost (20%)	\$	18,900	\$	18,900				\$ 37,800
Construction Cost			\$	62,967	\$ 62,967	\$	62,967	\$ 188,900
Contingency (40%)			\$	25,200	\$ 25,200	\$	25,200	\$ 75,600
Total Capital Cost	\$	18,900	\$	107,067	\$ 88,167	\$	88,167	\$ 302,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

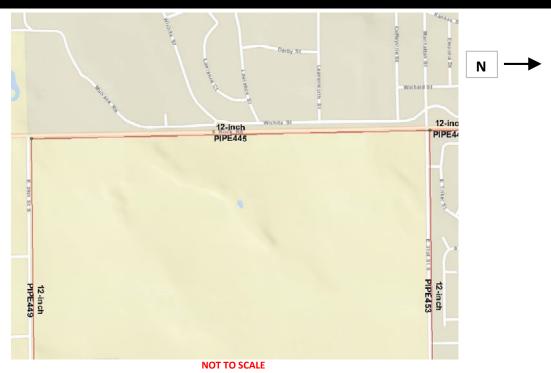
	2045-East-G-1											
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE443	12	2196	Growth	East	2045							

NOT TO SCALE

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 11,900	\$ 11,900				\$ 23,700
Construction Cost		\$ 39,500	\$ 39,500	\$	39,500	\$ 118,600
Contingency (40%)		\$ 15,800	\$ 15,800	\$	15,800	\$ 47,400
Total Capital Cost	\$ 11,900	\$ 67,200	\$ 55,300	\$	55,300	\$ 189,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Rock Road Between 31st St and 39th St



2045-East-G-2										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE445	12	5290	Growth	East	2045					

Capital Cost Opinion		Yea	ar			Total
Components	2042	2043		2044	2045	\$
Design Cost (20%)	\$ 28,600	\$ 28,600				\$ 57,100
Construction Cost		\$ 95,200	\$	95,200	\$ 95,200	\$ 285,700
Contingency (40%)		\$ 38,100	\$	38,100	\$ 38,100	\$ 114,300
Total Capital Cost	\$ 28,600	\$ 161,900	\$	133,300	\$ 133,300	\$ 457,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Webb Rd Between Carson St and 31st St 12-inch PIPE447 Note: Within Rd. PIPE447

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2045-East-G-3										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year					
PIPE447	12	4715	Growth	East	2045					

Capital Cost Opinion			Total				
Components	2042	2043	2044		2045		\$
Design Cost (20%)	\$ 25,500	\$ 25,500				\$	50,900
Construction Cost		\$ 84,900	\$ 84,900	\$	84,900	\$	254,600
Contingency (40%)		\$ 33,900	\$ 33,900	\$	33,900	\$	101,800
Total Capital Cost	\$ 25,500	\$ 144,300	\$ 118,800	\$	118,800	\$	407,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

39th St Between Rock Rd and Webb Rd 12-inch PIPE449 E 39th St S PIPE449 E 39th St S

NOT TO SCALE

2045-East-G-4										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE449*	12	5148	Growth	East	2045					

Capital Cost Opinion		Ye	ar			Total
Components	2042	2043		2044	2045	\$
Design Cost (20%)	\$ 27,800	\$ 27,800				\$ 55,600
Construction Cost		\$ 92,700	\$	92,700	\$ 92,700	\$ 278,000
Contingency (40%)		\$ 37,100	\$	37,100	\$ 37,100	\$ 111,200
Total Capital Cost	\$ 27,800	\$ 157,600	\$	129,800	\$ 129,800	\$ 444,800

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Webb Rd Between 31st St and 39th St



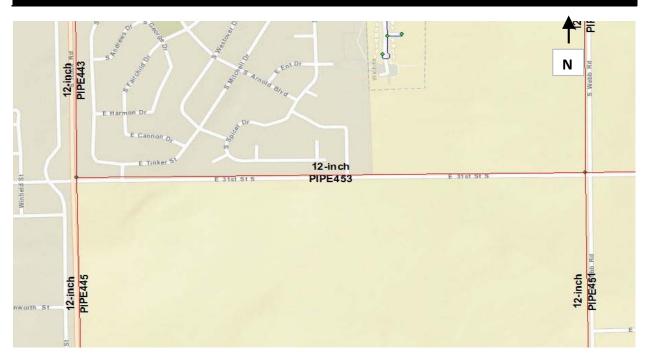
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2045-East-G-5											
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE451*	12	5289	Growth	East	2045						

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 28,600	\$ 28,600				\$ 57,100
Construction Cost		\$ 95,200	\$ 95,200	\$	95,200	\$ 285,600
Contingency (40%)		\$ 38,100	\$ 38,100	\$	38,100	\$ 114,200
Total Capital Cost	\$ 28,600	\$ 161,900	\$ 133,300	\$	133,300	\$ 456,900

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

31st St Between Rock Rd and Webb Rd



NOT TO SCALE

2045-East-G-6										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE453	12	5178	Growth	East	2045					

Capital Cost Opinion		Υ	ear			Total
Components	2042	2043		2044	2045	\$
Design Cost (20%)	\$ 28,000	\$ 28,000				\$ 55,900
Construction Cost		\$ 93,200	\$	93,200	\$ 93,200	\$ 279,600
Contingency (40%)		\$ 37,300	\$	37,300	\$ 37,300	\$ 111,800
Total Capital Cost	\$ 28,000	\$ 158,500	\$	130,500	\$ 130,500	\$ 447,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

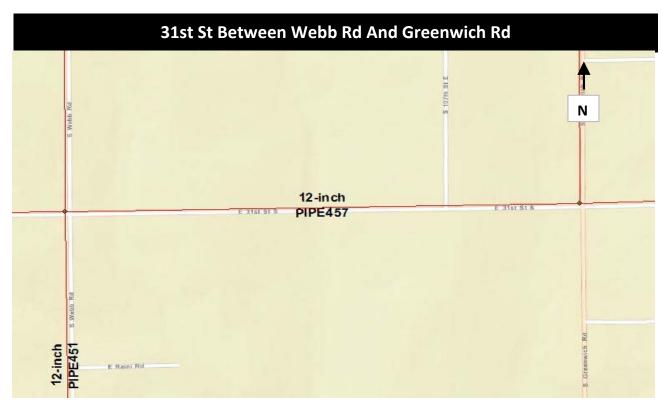
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	2045-East-G-7										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE455*	12	5241	Growth	East	2045						

NOT TO SCALE

Capital Cost Opinion				Yea	r				Total
Components	2042			2043 2044		2045		\$	
Design Cost (20%)	\$	28,300	\$	28,300					\$ 56,600
Construction Cost			\$	94,300	\$	94,300	\$	94,300	\$ 283,000
Contingency (40%)			\$	37,700	\$	37,700	\$	37,700	\$ 113,200
Total Capital Cost	\$	28,300	\$	160,300	\$	132,000	\$	132,000	\$ 452,800

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

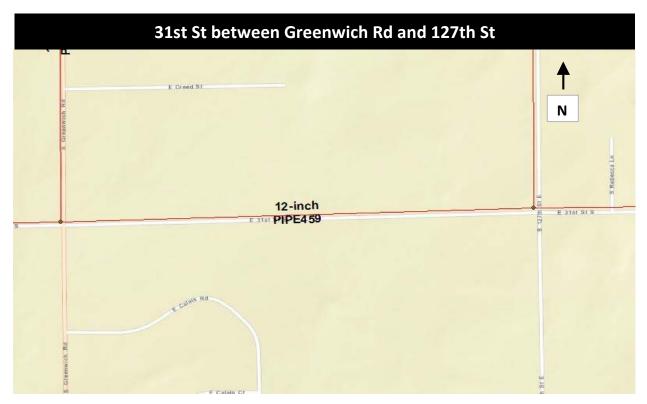


NOT TO SCALE

	2045-East-G-8										
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year						
PIPE457*	12	5333	Growth	East	2045						

Capital Cost Opinion		,	Yeaı	•	Year									
Components	2042	2043		2044	2045		\$							
Design Cost (20%)	\$ 28,800	\$ 28,800				\$	57,600							
Construction Cost		\$ 96,000	\$	96,000	\$ 96,000	\$	288,000							
Contingency (40%)		\$ 38,400	\$	38,400	\$ 38,400	\$	115,200							
Total Capital Cost	\$ 28,800	\$ 163,200	\$	134,400	\$ 134,400	\$	460,800							

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



NOT TO SCALE

	2045-East-G-9										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE459*	12	5270	Growth	East	2045						

Capital Cost Opinion		Υ	ear					Total	
Components	2042	2043		2044		2045	\$		
Design Cost (20%)	\$ 28,500	\$ 28,500					\$	56,900	
Construction Cost		\$ 94,900	\$	94,900	\$	94,900	\$	284,600	
Contingency (40%)		\$ 37,900	\$	37,900	\$	37,900	\$	113,800	
Total Capital Cost	\$ 28,500	\$ 161,300	\$	132,800	\$	132,800	\$	455,300	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

31st Street Between 127th St and 143rd St



NOT TO SCALE

	2045-East-G-10										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE461*	12	5309	Growth	East	2045						

Capital Cost Opinion	ion Year									Total
Components		2042	2043		2044		2045			\$
Design Cost (20%)	\$	28,700	\$	28,700					\$	57,300
Construction Cost			\$	95,600	\$	95,600	\$	95,600	\$	286,700
Contingency (40%)			\$	38,200	\$	38,200	\$	38,200	\$	114,700
Total Capital Cost	\$	28,700	\$	162,500	\$	133,800	\$	133,800	\$	458,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

127th St Between Pawnee St and 31st St



NOT TO SCALE

	2045-East-G-13										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE467*	12	5218	Growth	East	2045						

Capital Cost Opinion			Yea	ar		Total	
Components	2042	2043		2044	2045	\$	
Design Cost (20%)	\$ 28,200	\$ 28,200				\$ 56,300	
Construction Cost		\$ 93,900	\$	93,900	\$ 93,900	\$ 281,700	
Contingency (40%)		\$ 37,600	\$	37,600	\$ 37,600	\$ 112,700	
Total Capital Cost	\$ 28,200	\$ 159,700	\$	131,500	\$ 131,500	\$ 450,700	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



	2045-East-G-14										
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year										
PIPE473	12	1045	Growth	East	2045						

Capital Cost Opinion		Year									
Components	204	2	20	43		2044		2045	\$		
Design Cost (20%)					\$	11,300			\$	11,300	
Construction Cost					\$	28,200	\$	28,200	\$	56,400	
Contingency (40%)					\$	11,300	\$	11,300	\$	22,600	
Total Capital Cost	\$	-	\$	-	\$	50,800	\$	39,500	\$	90,300	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

143rd St Between Pawnee St and 31st St



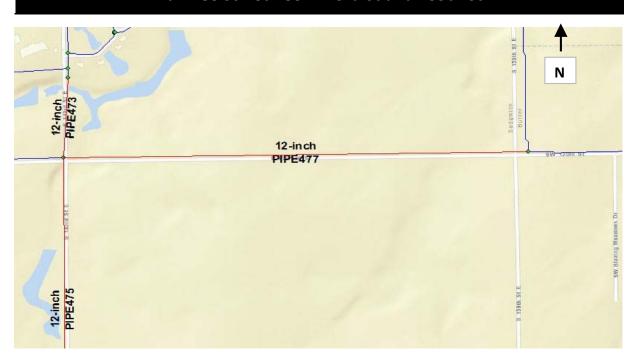
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		2045-East-G-1	.5		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE475*	12	5278	Growth	East	2045

Capital Cost Opinion		Year				Total	
Components	2042	2043 2044			2045		\$
Design Cost (20%)	\$ 28,500	\$ 28,500				\$	57,000
Construction Cost		\$ 95,000	\$	95,000	\$ 95,000	\$	285,000
Contingency (40%)		\$ 38,000	\$	38,000	\$ 38,000	\$	114,000
Total Capital Cost	\$ 28,500	\$ 161,500	\$	133,000	\$ 133,000	\$	456,000

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Pawnee St Between 143rd St and 159th St



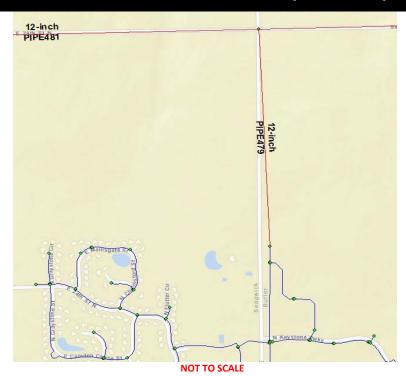
NOT TO SCALE

		2045-East-G	i-16						
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year								
PIPE477*	12	5476	Growth	East	2045				

Capital Cost Opinion		Total						
Components	2042	2043 2044			2045			\$
Design Cost (20%)	\$ 29,600	\$ 29,600					\$	59,100
Construction Cost		\$ 98,600	\$	98,600	\$	98,600	\$	295,700
Contingency (40%)		\$ 39,400	\$	39,400	\$	39,400	\$	118,300
Total Capital Cost	\$ 29,600	\$ 167,600	\$	138,000	\$	138,000	\$	473,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

159th St Between 29th St and Keystone Pkwy





		2045-East-G	-17							
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE479	12	2847	Growth	East	2045					

Capital Cost Opinion			Total						
Components	2042	2043	2044			2045	\$		
Design Cost (20%)	\$ 15,400	\$ 15,400					\$	30,700	
Construction Cost		\$ 51,200	\$	51,200	\$	51,200	\$	153,700	
Contingency (40%)		\$ 20,500	\$	20,500	\$	20,500	\$	61,500	
Total Capital Cost	\$ 15,400	\$ 87,100	\$	71,700	\$	71,700	\$	245,900	

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

29th St Between 143rd St and 159th St



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	2	045-East-G-	18							
Model ID	Model ID Diameter (in) Length (ft) Trigger Pressure Zone CIP Year									
PIPE481*	12	5279	Growth	East	2045					

Capital Cost Opinion		Total						
Components	2042	2043 2044		2045			\$	
Design Cost (20%)	\$ 28,500	\$ 28,500					\$	57,000
Construction Cost		\$ 95,000	\$	95,000	\$	95,000	\$	285,100
Contingency (40%)		\$ 38,000	\$	38,000	\$	38,000	\$	114,000
Total Capital Cost	\$ 28,500	\$ 161,500	\$	133,000	\$	133,000	\$	456,100

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

143rd St Between 29th St and 24th St



NOT TO SCALE

		2045-East-	G-19		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE483	12	2648	Growth	East	2045

Capital Cost Opinion		Total					
Components	2042	2043			2044	2045	\$
Design Cost (20%)	\$ 14,300	\$	14,300				\$ 28,600
Construction Cost		\$	47,700	\$	47,700	\$ 47,700	\$ 143,000
Contingency (40%)		\$	19,100	\$	19,100	\$ 19,100	\$ 57,200
Total Capital Cost	\$ 14,300	\$	81,100	\$	66,800	\$ 66,800	\$ 228,800

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

29th St Between 127th St and 143rd St N 12-inch PIPE485

NOT TO SCALE

		2045-East-	G-20		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE485	12	5373	Growth	East	2045

Capital Cost Opinion		Total				
Components	2042	2043	2044	2045		\$
Design Cost (20%)	\$ 29,000	\$ 29,000			\$	58,000
Construction Cost		\$ 96,700	\$ 96,700	\$ 96,700	\$	290,200
Contingency (40%)		\$ 38,700	\$ 38,700	\$ 38,700	\$	116,100
Total Capital Cost	\$ 29,000	\$ 164,400	\$ 135,400	\$ 135,400	\$	464,300

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

127th St Between 37th St and 29th St



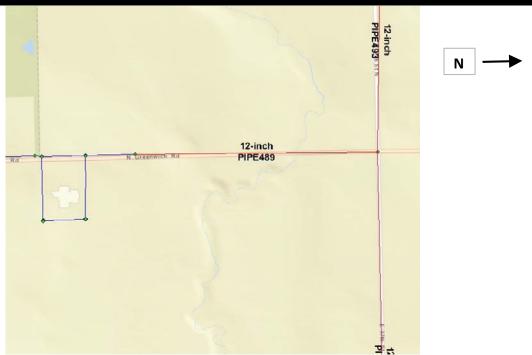
NOT TO SCALE

		2045-East-0	G-21		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE487	12	5411	Growth	East	2045

Capital Cost Opinion			Total			
Components	2042	2043	2044		2045	\$
Design Cost (20%)	\$ 29,200	\$ 29,200				\$ 58,400
Construction Cost		\$ 97,400	\$ 97,400	\$	97,400	\$ 292,200
Contingency (40%)		\$ 39,000	\$ 39,000	\$	39,000	\$ 116,900
Total Capital Cost	\$ 29,200	\$ 165,600	\$ 136,400	\$	136,400	\$ 467,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Greenwich Rd Between 37th Street and the Northeast Sports Complex



N	ΛT	• тс	١ د	$\Gamma \Lambda$	11

		2045-Eas	t-G-22		
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year
PIPE489	12	2855	Growth	East	2045

Capital Cost Opinion		Total					
Components	2042	2043		2044		2045	\$
Design Cost (20%)	\$ 15,400	\$ 15,400					\$ 30,800
Construction Cost		\$ 51,400	\$	51,400	\$	51,400	\$ 154,200
Contingency (40%)		\$ 20,600	\$	20,600	\$	20,600	\$ 61,700
Total Capital Cost	\$ 15,400	\$ 87,400	\$	72,000	\$	72,000	\$ 246,700

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

43rd St Between Webb Rd and Greenwich Rd



NOT TO SCALE

	2	045-Northea	st-G-1									
Model ID	Diameter (in)	Length (ft)	Trigger	Pressure Zone	CIP Year							
PIPE493												

Capital Cost Opinion		Total				
Components	2042	2043	2044	2045		\$
Design Cost (20%)	\$ 48,600	\$ 48,600			\$	97,200
Construction Cost		\$ 162,000	\$ 162,000	\$ 162,000	\$	485,900
Contingency (40%)		\$ 64,800	\$ 64,800	\$ 64,800	\$	194,400
Total Capital Cost	\$ 48,600	\$ 275,400	\$ 226,800	\$ 226,800	\$	777,500

- 1. CIP Designation definition = CIP Year-Pressure Zone-Trigger-Sequential Numbering Trigger: H = hydraulic (demand-driven); F = fire flow; G = growth (future development)
- 2. Contingency at 40 percent of the construction cost; mininum contingency cost is \$500.
- 3. Design at 20 percent of the construction cost; minimum design cost is \$1,000.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

WATER TREATMENT PLANT:
OPTION 1

LINEAR AND VERTICAL IMPROVEMENTS

Table 14.10
Water Treatment Vertical and Linear Improvements - Opinions of Probable Construction Cost: Option 1

	2035 Capital Improvements											
	Planning Start Capital Cost Components											
CIP Designation ¹	Trigger	Year	Unit	Construction	C	Daniau ³	Capital Cost					
		Teal		Construction	Contingency	Design ³	Opinion ⁴					
2035-Northwest WTP-R-1	Redundancy	2032	LS	\$133,120,000	\$39,940,000	\$13,310,000	\$186,370,000					
2035-Finished Water Transmission-R-2	Redundancy	2032	LS	\$28,020,000	\$11,210,000	\$5,600,000	\$44,830,000					
Subtotal 2035 Capital Cost Opinion \$231,200,000												

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: R = Redundancy.
- 2. Contingency at 30 percent of the construction cost for 2035-Northwest WTP-R-1; contingency at 40 percent for 2035-Finished Water Transmission-R2.
- 3. Design at 10 percent of the construction cost for 2035-Northwest WTP-R-1; design at 20 percent for 2035-Finished Water Transmission-R2.
- 4. Capital cost opinion includes construction, contingency, and design components.

2035 WTP Capital Planning Schedule: Option 1

		2035-N	ort	hwest WT	P-R	R-1			
Equipment								Trigger	CIP Year
Raw Water Storage							R	edundancy	2035
Supply Piping and Headworks Redu									2035
Clarification and Softening							R	edundancy	2035
Reverse Osmosis and Stabilization							R	edundancy	2035
Filtration							R	edundancy	2035
Disinfection and Other Chemical Feed							R	edundancy	2035
Finished Water Storage and Pumping							R	edundancy	2035
Residuals Handling							R	edundancy	2035
RO Concentrate Disposal							R	edundancy	2035
Capital Cost Opinion Components				Ye	ar				Total
Capital Cost Opinion Components		2032		2033		2034		2035	\$ (M)
Engineering Cost (10%)	\$	6,655,000	\$	6,655,000					\$ 13,310,000
Construction Cost			\$	44,373,000	\$	44,373,000	\$	44,373,000	\$ 133,120,000
Contingency (30%)			\$	13,313,000	\$	13,313,000	\$	13,313,000	\$ 39,940,000
Total Capital Cost	\$	6,655,000	\$	64,341,000	\$	57,686,000	\$	57,686,000	\$ 186,370,000

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

Option 1: 84" Finished Water Transmission





NOT TO SCALE

				OT TO SCALE					
2	203	5-Finished	l W	ater Trans	mi	ssion-R-2			
Equipment								Trigger	CIP Year
84-inch Transmission Main							R	edundancy	2035
Trenching and Backfilling							R	edundancy	2035
Trenchless Installations							R	edundancy	2035
Valves and Accessories							R	edundancy	2035
Connections							R	edundancy	2035
Surface Restoration							R	edundancy	2035
Conital Cost Oninion Components				Υ	ear	•			Total
Capital Cost Opinion Components		2032		2033		2034		2035	\$ (M)
Engineering Cost (20%)	\$	2,800,000	\$	2,800,000					\$ 5,600,000
Construction Cost			\$	9,340,000	\$	9,340,000	\$	9,340,000	\$ 28,020,000
Contingency (40%)			\$ 3	3,736,666.67	\$	3,736,666.67	\$ 3	3,736,666.67	\$ 11,210,000
Total Capital Cost	\$	2,800,000	\$	15,876,667	\$	13,076,667	\$	13,076,667	\$ 44,830,000

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

DISTRIBUTION SYSTEM AND WATER TREATMENT PLANT:
OPTION 2
LINEAR AND VERTICAL IMPROVEMENTS

Table 14.11
Distribution System Linear Improvements - Opinions of Probable Construction Cost: Option 2

			2035 Capital Imp	provements				
			Planning Start			Capital Cost	Components	
CIP Designation ¹	Model ID	Trigger	Year	Unit	Construction	Contingency ²	Design ³	Capital Cost
			Teal		Construction	Contingency	Design	Opinion ⁴
2035-Hess-Option 2-H-1	PIPE795, PIPE797	Hydraulic	2032	LS	\$16,040,000	\$6,420,000	\$3,210,000	\$25,670,000
						Subtotal 2035 Cap	ital Cost Opinion	\$25,670,000

Notes:

- CIP Designation definition = CIP Year-Pressure Zone-Option-Trigger-Sequential Numbering
 Trigger: H = Hydraulic; Option = Option 2
- 2. Contingency at 40 percent of the construction cost.
- 3. Design at 20 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

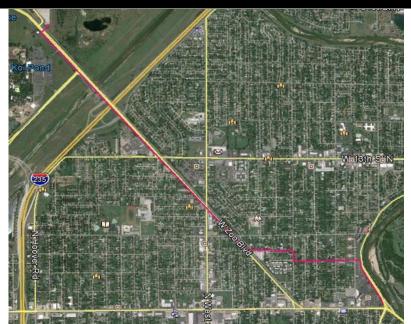
Table 14.12
Water Treatment Vertical Improvements - Opinions of Probable Construction Cost: Option 2

		2035 Ca	apital Improveme	ents			
		Diamaina Chash			Capital Cost	Components	
CIP Designation ¹	Trigger	Planning Start Year	Unit	Construction	Contingency ²	Design ³	Capital Cost Opinion ⁴
2035-Northwest WTP-R-1	Redundancy	2032	LS	\$133,120,000	\$39,940,000	\$13,310,000	\$186,370,000
				9	Subtotal 2035 Cap	ital Cost Opinion	\$186,370,000

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering Trigger: C = Capacity; R = Redundancy.
- 2. Contingency at 30 percent of the construction cost.
- 3. Design at 10 percent of the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.

Option 2: 66" Distribution System Transmission





		2	035	-Hess-Opti	on 2	2-H-1									
Equipment	quipment Trigge														
66-inch Transmission Main		Hydraulic		2035											
Trenching and Backfilling		Hydraulic		2035											
Trenchless Installations		Hydraulic		2035											
Valves and Accessories	Hydraulic		2035												
Connections															
Surface Restoration								Hydraulic		2035					
Capital Cost Opinion				Υe	ar					Total					
Components		2032		2033		2034		2035		\$ (M)					
Engineering Cost (20%)	\$	1,605,000	\$	1,605,000					\$	3,210,000					
Construction Cost			\$ 5,346,700		\$ 5,346,700		\$	16,040,000							
Contingency (40%)			\$	2,140,000	\$	2,140,000	\$	2,140,000	\$	6,420,000					
Total Capital Cost	\$	1,605,000	\$	9,091,700	\$	7,486,700	\$	7,486,700	\$	25,670,000					

Notes:

- 1. CIP Designation definition = CIP Year-Pressure Zone-Option-Trigger-Sequential Numbering Trigger: H = Hydraulic; Option = Option 2
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.

2035 WTP Capital Planning Schedule: Option 2

	2035-Northwest WTP-R-1														
Equipment								CIP Year		Trigger					
Raw Water Storage	<u> </u>														
Supply Piping and Headworks	R	Redundancy		2035											
Clarification and Softening	R	Redundancy		2035											
Reverse Osmosis and Stabilization	Redundancy		2035												
Filtration	R	Redundancy		2035											
Disinfection and Other Chemical Feed	Redundancy		2035												
Finished Water Storage and Pumping							R	Redundancy		2035					
Residuals Handling							R	Redundancy		2035					
RO Concentrate Disposal							R	Redundancy		2035					
Capital Cost Opinion Components				Υe	ear					Total					
Capital Cost Opinion Components		2032		2033		2034		2035		\$ (M)					
Engineering Cost (10%)	\$	6,655,000	\$	6,655,000					\$	13,310,000					
Construction Cost	Construction Cost \$ 44,373,000 \$ 44,373,000 \$														
Contingency (30%)	13,313,000	\$	39,940,000												
Total Capital Cost	\$	6,655,000	\$	64,341,000	\$	57,686,000	\$	57,686,000	\$	186,370,000					

Notes:

- 1. CIP Designation definition = CIP Year-Name-Trigger-Sequential Numbering
- 2. Contingency is a percentage of the construction cost.
- 3. Design is a percentage oc the construction cost.
- 4. Capital cost opinion includes construction, contingency, and design components.
- 5. Construction cost index for Kansas City, Q2 2016, is 11371.



PROJECTED WATER CASH FLOW Year Ended December 31 City of Wichita, Kansas BASE CASE

Line No. System Operations	(1) 2016 (\$)	(2) 2017 (\$)	(3) 2018 (\$)	(4) 2019 (\$)	(5) 2020 (\$)	(6) 2021 (\$)	(7) 2022 (\$)	(8) <u>2023</u> (\$)	(9) 2024 (\$)	(10) 2025 (\$)	(11) 2026 (\$)	(12) 2027 (\$)	(13) 2028 (\$)	(14) 2029 (\$)	(15) 2030 (\$)	(16) 2031 (\$)	(17) 2032 (\$)	(18) 2033 (\$)	(19) 2034 (\$)	(20) 2035 (\$)	(21) 2036 (\$)	(22) 2037 (\$)	(23) 2038 (\$)	(24) 2039 (\$)	(25) 2040 (\$)	(26) 2041 (\$)	(27) 2042 (\$)	(28) 2043 (\$)	(29) 2044 (\$)	(30) 2045 (\$)
1 Revenue from Water Sales - Existing Rates	74,286,900	89,808,900	93,001,000	99,557,000	106,529,800	106,919,000	107,277,100	107,707,200	108,096,400	108,485,700	108,843,700	109,332,600	109,721,900	110,111,100	110,541,200	110,899,300	111,288,500	111,777,500	112,166,700	112,565,600	112,755,400	112,855,100	113,013,600	113,144,700	113,344,100	113,443,800	113,602,300	113,733,400	113,891,900	114,032,500
Proposed Revenue Increases: Year	74,286,900	0 0	93,001,000	99.557,000	0 0 0 0	0 0 0 0 0	0 0 0 0 0 0	107,707,200 0 0 0 0 0 0	0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	108,843,700 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	110,111,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0	110,541,200 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	110,899,300 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	111,288,500 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	111,777,500 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	112,166,700 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	112,565,600 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	112,755,400 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	112,855,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	113,013,600	113,144,700 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	113,344,100	113,443,800	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	113,733,400 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	000000000000000000000000000000000000000
32 Total Proposed Additional Revenues 33 33 Total Water Sales Revenues													109,721,900	110,111,100	110,541,200												113,602,300	116,008,100	118,493,100	121,012,300
34 Other Revenues 35 Total Revenues	4,374,500 78,661,400	4,374,500 94,183,400	4,374,500 97,375,500	4,374,500 103,931,500	4,374,500 110,904,300	4,374,500 111,293,500	4,374,500 111,651,600			4,374,500 112,860,200			4,374,500 114,096,400				4,374,500 115,663,000		4,374,500 116,541,200		4,374,500 117,129,900	4,374,500 117,229,600		4,374,500 117,519,200		4,374,500 117,818,300	4,374,500 117,976,800	4,374,500 120,382,600	4,374,500 122,867,600	4,374,500 125,386,800
Operation and Maintenance Expenses		36,602,400 15,570,900																										79,694,500 21.036,700		
Other Operating Expenses and Capital Outlay 36 Total O&M Expense and Capital Outlay	49,097,200	52,173,300			53,592,800					60,954,300							73,602,200									94,924,100			103,845,700	
37 Outstanding Revenue Bond Debt Service Proposed Revenue Bond Debt Service:	25,164,000	22,227,100	21,869,600	20,272,500	20,439,800	20,331,400	19,701,800	19,623,200	17,286,700	17,299,600	16,121,400	15,363,100	15,262,500	13,172,100	13,077,700	8,998,700	7,313,100	5,170,700	5,062,200	3,157,600	2,732,000	2,077,300	1,970,000	1,859,200	0	0	0	0	0	0
Name	1	0 802,400	0 802,400 0	802,400 0 836,800	0 802,400 0 836,800 0	0 802,400 0 0 836,800 0 836,800	0 802,400 0 836,800 0 836,800 0	0 802,400 0 836,800 0 836,800 0 1,673,600	0 802,400 836,800 0 836,800 0 1,673,600	0 802,400 836,800 836,800 0 1,673,600 753,100	0 802,400 836,800 836,800 0 1,673,600 0 753,100	0 802,400 0 836,800 0 836,800 0 0 1,673,600 0 0 753,100 0 0	0 802,400 836,800 836,800 0 1,673,600 0 753,100 0 3,932,900	0 802,400 836,800 836,800 0 1,673,600 0 753,100 0 3,332,900 4,560,500	0 802,400 836,800 0 836,800 0 1,673,600 0 753,100 0 3,332,900 4,560,500 3,765,600	0 802,400 836,800 0 1,673,600 0 753,100 0 3,332,900 4,560,500 3,765,600	0 802,400 0 836,800 0 836,800 0 0 753,100 0 0 3,932,200 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 0 1,673,600 0 753,100 0 3,342,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 836,800 0 1,673,600 0 753,100 0 3,332,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 836,800 0 1,673,600 753,100 0 3,332,900 4,560,500 3,765,600 0	0 802,400 836,800 836,800 0 1,673,600 753,100 0 3,332,900 4,560,500 3,765,600 0 0	0 802,400 836,800 0 1,673,600 0 753,100 0 3,392,900 0 0 0 0 0 0 0 0	0 802,400 836,800 836,800 0 1,673,600 0 753,100 0 3,332,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 836,800 0 1,673,600 753,100 0 3,332,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 0 836,800 0 1,673,600 753,100 0 3,332,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 0 836,800 0 336,800 0 753,100 0 0 3,932,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 0 836,800 0 836,800 0 753,100 0 0 3,932,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	836,800 0 836,800 0	0 802,400 0 836,800 0 836,800 0 1,673,600 0 753,100 0 0 3,932,900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 836,800 0 1,673,600 0 753,100 0 0 3,332,990 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
67 2045 1 \$0 5.50% 20 68 Total Proposed Revenue Bond Debt Service	0	802,400	802,400	1,639,200	1,639,200	2,476,000	2,476,000	4,149,600	4,149,600	4,902,700	4,902,700	4,902,700	8,835,600	13,396,100	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700	17,161,700
69 Total Revenue Bond Debt Service		23,029,500					22,177,800						24,098,100					22,332,400		20,319,300	19,893,700	19,239,000	19,131,700	19,020,900	17,161,700	17,161,700	17,161,700	17,161,700		17,161,700
70 GO Bond Debt Service 71 Total Operating Expenses	9,651,400 83,912,600	9,648,700 84,851,500	9,639,700 85,279,300	9,633,900 83,480,300	9,630,400 85,302,200	9,623,600 87,398,200	9,613,100 88,178,200	9,608,100 91,240,700	9,597,900 90,415,000	9,591,600 92,748,200	9,655,800 93,260,200	9,650,600 94,185,500	9,648,700 99,757,800	9,645,000	9,639,300 109,558,000	9,594,500 107,361,400	9,587,400		9,586,400 109,618,800	100,339,000	102,191,000	103,888,800	106,219,500	108,630,700	109,385,300	112,085,800	114,884,000	117,892,900	121,007,400	124,228,900
72 Annual Operating Balance	(5,251,200)	9,331,900	12,096,200	20,451,200	25,602,100	23,895,300	23,473,400	20,841,000	22,055,900	20,112,000	19,958,000	19,521,600	14,338,600	10,459,400	5,357,700	7,912,400	7,998,600	8,554,700	6,922,400	16,601,100	14,938,900	13,340,800	11,168,600	8,888,500	8,333,300	5,732,500	3,092,800	2,489,700	1,860,200	1,157,900
73 Beginning Balance - Operating Funds 74 Funds from Annual Operating Balance 75 Transfer to Major Capital Improvement Financing 76 Ending Balance - Operating Funds	17,181,200 (5,251,200) (3,859,200) 8,070,800		(11,965,600)	(20,621,000)	(25,329,500)	(23,669,400)	9,035,700 23,473,400 (23,240,000) 9,269,100	20,841,000 (20,598,900)	(21,805,900)	20,112,000 (19,853,300)	19,958,000 (19,690,700)	(19,244,000)	(14,052,300)	10,459,400 (10,163,200)	11,147,300 5,357,700 (5,050,900) 11,454,100	7,912,400 (7,595,600)	11,770,900 7,998,600 (7,670,500) 12,099,000	(8,214,500)	(6,571,200)	16,601,100 (16,237,600)	(14,564,500)	13,340,800 (12,954,100)	11,168,600 (10,767,800)	14,315,800 8,888,500 (8,473,900) 14,730,400	8,333,300 (7,903,700)	15,160,000 5,732,500 (5,288,500) 15,604,000	(2,632,900)	(1,995,000)	16,558,600 1,860,200 (1,348,300) 17,070,500	1,157,900 (628,300)
77 Minimum Operating Fund Balance [1]	8,070,800	8,576,400	8,707,000	8,537,200	8,809,800	9,035,700	9,269,100	9,511,200	9,761,200	10,019,900	10,287,200	10,564,800	10,851,100	11,147,300	11,454,100	11,770,900	12,099,000	12,439,200	12,790,400	13,153,900	13,528,300	13,915,000	14,315,800	14,730,400	15,160,000	15,604,000	16,063,900	16,558,600	17,070,500	17,600,100
Major Capital Improvement Financing 8 Beginning Balance - Capital Funds 99 Bond or Note Issue 80 Issuance Costs 81 Debt Service Reserve	0 0	3,859,200 10,000,000 (200,000)	0	10,000,000 (200,000)	28,099,700 0 0	10,000,000 (200,000)	0	20,000,000 (400,000)	19,825,600	8,949,700 9,000,000 (180,000)	0	0	30,141,600 47,000,000 (940,000)	54,500,000 (1,090,000)	16,292,300 45,000,000 (900,000)	431,200 0 0	8,026,800 0 0	0	0	0	0	58,682,200 0 0	0	0	0	0	0	102,870,400	0	0
82 Transfer of Operating Funds 83 Total Available Capital Funds	3,859,200 3,859,200						23,240,000 44,968,700																					1,995,000 104,865,400	1,348,300 83,855,700	628,300 64,551,600
84 City CIP 85 Water Masterplan CIP 86 Ending Balance - Capital Funds 87 Target Fund Balance [2]	3,859,200 1,039,500	18,327,500	9,936,000		7,880,600	21,728,700	26,812,000 18,156,700 9,632,500	19,825,600	8,949,700	3,960,700	23,651,400 3,188,450	30,141,600		16,292,300	65,012,000 431,200 0	8,026,800 22,050	88,200 15,609,100 128,575	514,300 23,309,300 232,350	929,400 28,951,100 267,750	1,071,000 44,117,700 0	0 58,682,200 0	71,636,300 0	82,404,100 0	90,878,000 0	98,781,700 0			22,358,000 82,507,400 4,983,100		
Debt Service Coverage 88 Net Op Revenues Avail for Revenue Bond Debt Service 99 Annual Revenue Bond Debt Service 90 Total Debt Service Coverage Based on Net Op Revenues	42,615,300 25,164,000 1.69	57,581,000 23,029,500 2.50	60,150,000 22,672,000 2.65		74,244,800 22,079,000 3.36	73,390,900 22,807,400 3.22					68,410,200 21,024,100 3.25	67,368,300 20,265,800 3.32	66,172,700 24,098,100 2.75	64,921,100 26,568,200 2.44	63,652,300 30,239,400 2.10		60,819,200 24,474,800 2.48		57,858,700 22,223,900 2.60	56,235,500 20,319,300 2.77	54,331,500 19,893,700 2.73	52,263,100 19,239,000 2.72	50,176,400 19,131,700 2.62	47,982,500 19,020,900 2.52		43,380,300 17,161,700 2.53	40,956,600 17,161,700 2.39		40,403,600 17,161,700 2.35	
91 Net Op Revenues Avail for Revenue Bond Debt Service 92 Annual Total Debt Service (Revenue and G.O.) 93 Total Debt Service Coverage Based on Net Op Revenues	42,615,300 34,815,400 1.22	57,581,000 32,678,200 1.76		68,472,900 31,545,600 2.17			72,462,000 31,790,900 2.28				68,410,200 30,679,900 2.23		66,172,700 33,746,800 1.96				60,819,200 34,062,200 1.79			56,235,500 20,319,300 2.77	54,331,500 19,893,700 2.73		50,176,400 19,131,700 2.62	47,982,500 19,020,900 2.52		43,380,300 17,161,700 2.53	40,956,600 17,161,700 2.39		40,403,600 17,161,700 2.35	40,054,500 17,161,700 2.33

PROJECTED WATER CASH FLOW Year Ended December 31 City of Wichita, Kansas OPTION 1

Line No. System Operations	(1) 2016 (\$)	(2) 2017 (\$)	(3) 2018 (\$)	(4) 2019 (\$)	(5) 2020 (\$)	(6) 2021 (\$)	(7) 2022 (\$)	(8) 2023 (\$)	(9) 2024 (\$)	(10) 2025 (\$)	(11) 2026 (\$)	(12) 2027 (\$)	(13) 2028 (\$)	(14) 2029 (\$)	(15) 2030 (\$)	(16) 2031 (\$)	(17) 2032 (\$)	(18) 2033 (\$)	(19) 2034 (\$)	(20) 2035 (\$)	(21) 2036 (\$)	(22) 2037 (\$)	(23) 2038 (\$)	(24) 2039 (\$)	(25) 2040 (\$)	(26) 2041 (\$)	(27) 2042 (\$)	(28) 2043 (\$)	(29) 2044 (\$)	(30) 2045 (\$)
Revenue from Water Sales - Existing Rates	74,286,900		93,001,000	(,,	106,529,800	106,919,000	107,277,100	107,707,200	(-)	108,485,700	108,843,700	(,,	(1)	110,111,100	(,,	()	111,288,500	111,777,500	(, ,	(-,	112,755,400	(-,	113,013,600	113,144,700	.,,	113,443,800	113,602,300	(-,	(,,	114,032,500
Proposed Revenue Increases: Year Month Month Increase 2 2016 1 January 0.00% 3 2017 1 January 0.00% 4 2018 1 January 0.00% 5 2019 1 January 0.00% 6 2020 1 January 0.00% 7 2021 1 January 0.00% 8 2022 1 January 0.00% 9 2023 1 January 0.00% 10 2024 1 January 0.00% 11 2025 1 January 0.00% 11 2025 1 January 0.00% 12 2026 1 January 0.00% 13 2027 1 January 0.00% 15 2029 1 January 0.00% 16 2030 1 January 0.00% 17 2028 1 January 0.00% 18 2027 1 January 0.00% 19 2023 1 January 0.00% 19 2023 1 January 0.00% 10 2026 1 January 0.00% 11 2026 1 January 0.00% 12 2026 1 January 0.00% 13 2027 1 January 0.00% 14 2028 1 January 0.00% 15 2029 1 January 0.00% 16 2030 1 January 1.00% 17 2031 1 January 1.00% 18 2032 1 January 1.00% 19 2033 1 January 1.00% 20 2034 1 January 1.00% 21 2035 1 January 9.00% 22 2036 1 January 2.00% 23 2037 1 January 2.00% 24 2038 1 January 2.00% 25 2039 1 January 2.00% 26 2040 1 January 2.00% 27 2041 1 January 2.00% 28 2042 1 January 3.00% 31 2045 Total Proposed Additional Revenues	0	0 0	0 0 0	0 0 0 0	0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 1,148,580 1,148,580 1,198,800 10,959,800 11,946,200	0 0 0 0 0 0 0 0 0 0 0 0 0 1,138,800 1,150,250 5,808,600 10,978,300 11,966,300 5,797,000	0 0 0 0 0 0 0 0 0 0 0 0 0 0 1,139,800 1,151,200 1,918,900 1,197,900 5,802,100 3,017,100	0 0 0 0 0 0 0 0 0 0 0 0 1,141,400 1,162,980 5,821,980 11,093,400 11,193,700 5,810,380 3,021,380 3,021,380	0 0 0 0 0 0 0 0 0 0 0 0 1,131,400 1,154,200 5,828,700 11,016,200 12,007,600 5,817,000 3,024,900 3,024,900 3,024,900 3,147,100	0 0 0 0 0 0 0 0 0 0 0 1,144,800 1,156,200 5,233,900 11,035,600 3,302,200 3,152,600 3,215,700	0 0 0 0 0 0 0 0 0 0 0 0 1,143,400 1,157,200 5,844,100 5,832,400 3,032,800 3,032,800 3,155,400 3,155,600 3,125,000 3,	0 0 0 0 0 0 0 0 0 0 0 1,145,900 5,852,200 11,060,700 12,056,200 3,097,100 3,097,900 3,159,800 3,223,000 3,223,000 3,237,100 3,237,400 3,237,400 3,237,400 3,237,400	0 0 0 0 0 0 0 0 0 0 0 0 0 1,148,700 1,160,200 5,889,000 11,073,500 12,070,100 5,847,300 3,101,400 3,103,406,600 3,101,400 3,228,700 3,228,700 3,221,200 3,321,200 5,341,300	0 0 0 0 0 0 0 0 0 0 1,150,300 1,161,800 5,867,100 11,088,900 5,857,100 11,088,900 3,044,800 3,167,800 3,231,200 3,231,200 5,231,200 6,23	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
33 Total Water Sales Revenues 34 Other Revenues 35 Total Revenues	74,286,900 4,374,500 78,661,400	89,808,900 4,374,500 94,183,400	4,374,500	4,374,500	4,374,500	4,374,500	107,277,100 4,374,500 111,651,600	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500	4,374,500
Operation and Maintenance Expenses Other Operating Expenses and Capital Outlay Total O&M Expense and Capital Outlay	36,046,100 13,051,100 49,097,200	36,602,400 15,570,900 52,173,300	37,225,500 15,742,100 52,967,600	35,458,600 16,476,100 51,934,700			39,189,600 17,197,700 56,387,300		41,901,400 17,479,400 59,380,800								54,843,800 18,927,000 73,770,800								71,944,500 22,811,800 94,756,300	23,185,200				
37 Additional O&M																				12,559,000	17,265,000	17,866,000	18,491,000	19,135,000	19,804,000	20,497,000	21,213,000	21,956,000	22,723,000	23,518,000
38 Outstanding Revenue Bond Debt Service	25,164,000	22,227,100	21,869,600	20,272,500	20,439,800	20,331,400	19,701,800	19,623,200	17,286,700	17,299,600	16,121,400	15,363,100	15,262,500	13,172,100	13,077,700	8,998,700	7,313,100	5,170,700	5,062,200	3,157,600	2,732,000	2,077,300	1,970,000	1,859,200	0	0	0	0	0	0
Proposed Revenue Bond Debt Service: Year Monunt Notes Term 39 2016 1 \$0 4.50% 20 41 2017 1 \$10,000,000 5.00% 20 41 2018 1 \$10,000,000 5.00% 20 43 2020 1 \$10,000,000 5.50% 20 43 2020 1 \$10,000,000 5.50% 20 44 2021 1 \$10,000,000 5.50% 20 45 2022 1 \$10,000,000 5.50% 20 45 2022 1 \$10,000,000 5.50% 20 46 2023 1 \$20,000,000 5.50% 20 47 2024 1 \$0 5.50% 20 48 2025 1 \$20,000,000 5.50% 20 49 2026 1 \$20,000,000 5.50% 20 20 49 2026 1 \$24,000,000 5.50% 20 20 20 20 20 20 20		802,400	802,400 802,400	802,400 0 836,800	802,400 0 836,800 0	802,400 0 836,800 0 836,800	802,400 0 336,800 0 836,800 0	802,400 0 836,800 0 836,800 1,673,600	802,400 0 836,800 0 836,800 0 1,673,600	0 802,400 0 836,800 0 1,673,600 0 2,008,300	802,400 0 836,800 0 1,673,600 0 2,008,300 0	802,400 0 836,800 0 836,800 0 1,673,600 0 0 2,008,300 0	802,400 0 836,800 0 836,800 0 1,673,600 0 2,008,300 5,439,200	802,400 0 836,800 0 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800	802,400 0 836,800 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 4,602,400	802,400 0 836,800 0 0 1,673,600 0 2,008,300 5,439,200 5,020,800 0 0	802,400 0 836,800 0 0 336,800 0 1,673,600 0 2,008,300 0 5,439,200 0 5,020,800 0 0 0 0 0 0 0 0 0 0 0 0	802,400 0 836,800 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 0 0 5,020,800 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	802,400 0 836,800 0 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 4,602,400 0 10,878,300 10,041,500	802,400 0 836,800 0 0 836,800 0 1,673,600 0 2,008,300 0 5,439,20 5,020,800 1,602,400 0 10,878,300 10,041,500 7,698,500	802,400 0 836,800 0 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 4,602,400 0 10,878,300 10,041,500 7,698,500	802,400 0 836,800 0 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 0 10,878,300 10,041,500 7,698,500 0	802,400 0 836,800 0 0 1,673,600 0 2,008,300 0 0,5,439,200 5,020,800 0 0 10,878,300 10,041,500 7,698,500	802,400 0 836,800 0 836,800 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	802,400 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 0 10,674,500 7,698,500 0 0	0 802,400 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 0 0 10,763,900 10,041,500 7,698,500	802,400 0 836,800 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 0 10,041,500 7,698,500	802,400 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 0 10,878,300 10,041,500 7,698,500 0 1,087,800	802,400 0 836,800 0 1,673,600 0 2,008,300 0 5,439,200 5,020,800 0 10,878,300 10,041,500 7,698,500 0 1,087,830 0 1,087,830 0 5,200,830 1,087,830 0 0 0 0 0 0 0 0 1,087,830 0 0 0 0 0 0 0 0 0 0 0 0 0	802,400 0 836,800 0 836,800 0 0 1,673,600 0 2,008,300 0 0 5,439,200 5,020,800 4,602,400 0 0 10,878,300 10,041,500 7,698,500 0 0 0 0 1,087,800 1,087,
40 Total Revenue Bond Debt Service	25,164,000	23,029,500	22,672,000	21,911,700	22,079,000	22,807,400	22,177,800	23,772,800	21,436,300	23,457,500	22,279,300	21,521,000	26,859,600	29,790,000	34,298,000	30,219,000	28,533,400	37,269,300	47,202,300	52,996,200	52,570,600	51,915,900	51,808,600	51,697,800	49,838,600	49,838,600	49,838,600	50,926,400	52,348,900	53,436,700
41 GO Bond Debt Service	9,651,400	9,648,700	9,639,700	9,633,900	9,630,400	9,623,600	9,613,100	9,608,100	9,597,900	9,591,600	9,655,800	9,650,600	9,648,700	9,645,000	9,639,300	9,594,500	9,587,400	9,592,900	9,586,400	0	0	0	0	0	0	0	0	0	0	0
42 Total Operating Expenses 43 Annual Operating Balance	83,912,600 (5,251,200)	9,331,900	85,279,300 12,096,200	83,480,300 20,451,200	85,302,200 25,602,100	87,398,200 23,895,300		91,240,700 20,841,000	90,415,000 22,055,900	94,003,400 18,856,800	94,515,400 18,702,800	95,440,700 18,266,400	102,519,300	7,237,600	2,349,200	5,971,500	7,143,600	2,305,700	1,037,100	1,875,100	1,065,500	1,764,400	1,949,700	2,064,200	164,398,900 3,974,000	3,841,200	3,742,500	4,090,200	4,176,400	4,601,900
44 Beginning Balance - Operating Funds 45 Funds from Annual Operating Balance 46 Transfer to Major Capital Improvement Financing 47 Ending Balance - Operating Funds	17,181,200 (5,251,200) (3,859,200) 8,070,800	8,070,800 9,331,900 (8,826,300) 8,576,400		8,707,000 20,451,200 (20,621,000) 8,537,200			9,035,700 23,473,400 (23,240,000) 9,269,100		9,511,200 22,055,900 (21,805,900) 9,761,200		(18,435,500)		(11,290,800)	10,851,100 7,237,600 (6,941,400) 11,147,300	11,147,300 2,349,200 (2,033,300) 11,463,200	11,463,200 5,971,500 (5,645,500) 11,789,200	(6,806,100)	(1,918,000)	12,514,400 1,037,100 (595,900) 12,955,600	12,955,600 1,875,100 0 14,830,700	14,830,700 1,065,500 0 15,896,200	15,896,200 1,764,400 (471,600) 17,189,000	17,189,000 1,949,700 (1,420,400) 17,718,300	17,718,300 2,064,200 (1,517,400) 18,265,100	18,265,100 3,974,000 (3,407,300) 18,831,800	18,831,800 3,841,200 (3,256,000) 19,417,000	19,417,000 3,742,500 (3,136,600) 20,022,900	(3,449,400)	4,176,400 (3,513,200)	21,326,900 4,601,900 (3,915,600) 22,013,200
48 Minimum Operating Fund Balance [1]	8,070,800	8,576,400	8,707,000	8,537,200	8,809,800	9,035,700	9,269,100	9,511,200	9,761,200	10,019,900	10,287,200	10,564,800	10,851,100	11,147,300	11,463,200	11,789,200	12,126,700	12,514,400	12,955,600	15,482,400	16,678,500	17,189,000	17,718,300	18,265,100	18,831,800	19,417,000	20,022,900	20,663,700	21,326,900	22,013,200
Major Capital Improvement Financing 48 Beginning Balance - Capital Funds 50 Bond or Note Issue 51 Issuance Costs 52 Dett Service Reserve 53 Transfer of Operating Funds 54 Total Available Capital Funds	0 0 3,859,200 3,859,200				0 0 25,329,500		21,728,700 0 0 23,240,000 44,968,700		21,805,900		0 0 18,435,500	17,988,800	65,000,000 (1,300,000) 11,290,800	60,000,000 (1,200,000) 6,941,400	55,000,000 (1,100,000) 2,033,300	0 0 5,645,500	0 0 6,806,100	130,000,000 (2,600,000) 1,918,000	595,900	92,000,000 (1,840,000)	1,832,000 0 0 0	1,832,000 0 0 471,600 2,303,600	2,303,600 0 0 1,420,400 3,724,000	3,724,000 0 0 1,517,400 5,241,400	5,241,400 0 0 3,407,300 8,648,700	0 0 3,256,000	0 0 3,136,600	11,208,600 13,000,000 (260,000) 3,449,400 27,398,000	5,040,000 17,000,000 (340,000) 3,513,200 25,213,200	5,280,800 13,000,000 (260,000) 3,915,600 21,936,400
55 City CIP 56 Water Masterplan CIP 57 Ending Balance - Capital Funds 58 Target Fund Balance [2]	3,859,200 1,039,500	4,158,000 18,327,500 5,089,275	9,936,000	12,257,300 28,099,700 11,387,150	7,880,600	19,621,300 21,728,700 6,703,000	18,156,700	38,530,000 19,825,600 8,170,450	32,681,800 8,949,700 8,415,575	17,405,500	35,841,000	12,753,800 41,076,000 18,604,100	41,650,400		35,194,700	40,840,200		32,905,300		121,539,800 1,832,000 0	0 1,832,000 0	0 2,303,600 0	0 3,724,000 0	5,241,400 0	0 8,648,700 0	0 11,904,700 958,175	3,832,700 11,208,600 5,589,500	22,358,000 5,040,000 4,983,100	19,932,400 5,280,800 5,077,125	20,308,500 1,627,900 0
Debt Service Coverage 59 Net Op Revenues Avail for Revenue Bond Debt Service 60 Annual Revenue Bond Debt Service	42,615,300 25,164,000	57,581,000 23,029,500	60,150,000 22,672,000	68,472,900 21,911,700	74,244,800 22,079,000	73,390,900 22,807,400	72,462,000 22,177,800	71,559,700 23,772,800	70,569,500 21,436,300	69,530,700 23,457,500	68,410,200 22,279,300	67,368,300 21,521,000	66,172,700 26,859,600	64,921,100 29,790,000	64,757,700 34,298,000	64,480,500 30,219,000	64,191,400 28,533,400	68,567,500 37,269,300	77,956,700 47,202,300	75,792,200 52,996,200 1.43	75,033,300 52,570,600	75,414,500 51,915,900	75,842,200 51,808,600 1.46	76,202,800 51,697,800 1.47	76,624,400 49,838,600 1.54	76,865,000 49,838,600 1.54	77,153,800 49,838,600	79,070,200 50,926,400 1.55	81,076,800 52,348,900	83,101,800 53,436,700
61 Total Debt Service Coverage Based on Net Op Revenues 62 Net Op Revenues Avail for Revenue Bond Debt Service 63 Annual Total Debt Service (Revenue and G.O.) 64 Total Debt Service Coverage Based on Net Op Revenues	1.69 42,615,300 34,815,400 1.22	2.50 57,581,000 32,678,200 1.76	2.65 60,150,000 32,311,700 1.86	3.12 68,472,900 31,545,600 2.17	3.36 74,244,800 31,709,400 2.34	3.22 73,390,900 32,431,000 2.26	3.27 72,462,000 31,790,900 2.28	3.01 71,559,700 33,380,900 2.14	3.29 70,569,500 31,034,200 2.27	2.96 69,530,700 33,049,100 2.10		3.13 67,368,300 31,171,600 2.16	2.46 66,172,700 36,508,300 1.81	2.18 64,921,100 39,435,000 1.65	1.89 64,757,700 43,937,300 1.47	2.13 64,480,500 39,813,500 1.62	2.25 64,191,400 38,120,800 1.68	1.84 68,567,500 46,862,200 1.46		75,792,200 52,996,200 1.43	1.43 75,033,300 52,570,600 1.43	75,414,500 51,915,900 1.45	75,842,200 51,808,600 1.46	76,202,800	76,624,400 49,838,600 1.54	76,865,000	1.55 77,153,800 49,838,600 1.55	79,070,200 50,926,400 1.55	1.55 81,076,800 52,348,900 1.55	1.56 83,101,800 53,436,700 1.56

PROJECTED WATER CASH FLOW Year Ended December 31 City of Wichita, Kansas OPTION 2

Line No. System Operations	(1) 2016 (\$)	(2) 2017 (\$)	(3) 2018 (\$)	(4) 2019 (\$)	(5) 2020 (\$)	(6) 2021 (\$)	(7) 2022 (\$)	(8) 2023 (\$)	(9) 2024 (\$)	(10) 2025 (\$)	(11) 2026 (\$)	(12) 2027 (\$)	(13) 2028 (\$)	(14) 2029 (\$)	(15) 2030 (\$)	(16) 2031 (\$)	(17) 2032 (\$)	(18) 2033 (\$)	(19) 2034 (\$)	(20) 2035 (\$)	(21) 2036 (\$)	(22) 2037 (\$)	(23) 2038 (\$)	(24) 2039 (\$)	(25) 2040 (\$)	(26) 2041 (\$)	(27) 2042 (\$)	(28) 2043 (\$)	(29) 2044 (\$)	(30) 2045 (\$)
1 Revenue from Water Sales - Existing Rates	74,286,900	89,808,900	93,001,000	99,557,000	106,529,800	106,919,000	107,277,100	107,707,200	108,096,400	108,485,700	108,843,700	109,332,600	109,721,900	110,111,100	110,541,200	110,899,300	111,288,500	111,777,500	112,166,700	112,565,600	112,755,400	112,855,100	113,013,600	113,144,700	113,344,100	113,443,800	113,602,300	113,733,400	113,891,900	114,032,500
Proposed Revenue Increases:																														
Year Month Month Increase 2 2016 1 January 0.00% 3 2017 1 January 0.00% 4 2018 1 January 0.00% 5 2019 1 January 0.00% 6 2020 1 January 0.00% 7 2021 1 January 0.00% 8 2022 1 January 0.00% 9 2023 1 January 0.00% 10 2024 1 January 0.00% 11 2025 1 January 0.00% 12 2026 1 January 0.00% 13 2027 1 January 0.00% 14 2028 1 January 0.00% 15 2029 1 January 0.00% 16 2030 1 January 0.00% <t< td=""><td>0</td><td>0 0</td><td>0 0 0</td><td>0 0 0 0</td><td>0 0 0 0 0</td><td>0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td></td><td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td></t<>	0	0 0	0 0 0	0 0 0 0	0 0 0 0 0	0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
33 33 Total Water Sales Revenues 34 Other Revenues	74,286,900 4.374.500	89,808,900 4,374,500																							162,278,100 4,374,500					183,808,200
35 Total Revenues	78,661,400	94,183,400	97,375,500	103,931,500	110,904,300	111,293,500	111,651,600	112,081,700	112,470,900	112,860,200	113,218,200	113,707,100	114,096,400	114,485,600	114,915,700										166,652,600					188,182,700
36 Operation and Maintenance Expenses 37 Additional O&M	49,097,200	52,173,300	52,967,600	51,934,700	53,592,800	54,967,200	56,387,300	57,859,800	59,380,800	60,954,300	62,580,300	64,269,100	66,011,000	67,813,000	69,679,300	71,606,500	73,602,200	76,119,100	78,741,700	81,481,400 12,559,000	84,116,600 17,265,000	86,620,000 17,866,000	89,213,200 18,491,000	91,893,300 19.135.000	94,670,300		100,503,200 21,213,000			110,207,000 23.518.000
37 Outstanding Revenue Bond Debt Service	25.164.000	22.227.100	21.869.600	20.272.500	20.439.800	20.331.400	19.701.800	19.623.200	17.286.700	17.299.600	16.121.400	15.363.100	15.262.500	13.172.100	13.077.700	8.998.700	7.313.100	5.170.700	5.062.200	3.157.600	2.732.000	2.077.300	1.970.000	1.859.200	19,804,000	20,497,000	21,213,000	21,956,000	22,723,000	23,518,000
Proposed Revenue Bond Debt Service:																														
Year Month Amount Interest Lens 38 2016 1 \$0 4.50% 20 39 2017 1 \$10,000,000 5.00% 20 40 2018 1 \$0,000,000 5.50% 20 41 2019 1 \$10,000,000 5.50% 20 42 2020 1 \$0,000,000 5.50% 20 43 2021 1 \$10,000,000 5.50% 20 45 2023 1 \$20,000,000 5.50% 20 46 2024 1 \$0 5.50% 20 47 2025 1 \$20,000,000 5.50% 20 48 2026 1 \$0 5.50% 20 50 2028 1 \$55,000,000 5.50% 20 51 2029 1 \$59,000,000 5.50% 20 52 2030 1 \$59,000,000 5	0	0 802,400	0 802,400 0	0 802,400 836,800	802,400 836,800 0	0 802,400 0 836,800 0 836,800 2,476,000	0 802,400 0 836,800 0 836,800 0	0 802,400 836,800 836,800 0 1,673,800	0 802,400 836,800 836,800 1,673,600 0	0 802,400 836,800 936,800 1,673,800 1,673,600	0 802,400 836,800 9,836,800 1,673,600 1,673,600 0	0 802,400 836,800 836,800 1,673,600 0 1,673,600 0	0 802,400 836,800 936,800 1,673,600 0 1,673,600 0 5,439,200	0 802,400 836,800 936,800 1,673,800 0 1,673,800 0 5,439,200 4,937,100	0 802,400 836,800 936,800 1,673,800 0 1,673,800 0 5,439,270 4,937,100	0 802,400 836,800 836,800 1,673,800 0 1,673,800 0 5,439,200 4,937,100 4,937,100	802,400 836,800 836,800 1,673,600 1,673,600 1,673,600 0 5,439,200 4,937,100 0 0	0 802,400 0 836,800 0 836,800 0 1,673,600 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	802,400 836,800 836,800 1,673,600 1,673,600 1,673,600 4,937,100 4,937,100 9,790,500 9,204,700	0 802,400 836,800 936,800 1,673,600 0 1,673,600 0 5,439,200 0 9,790,500 9,790,500 9,204,700 7,531,100	0 802,400 0 836,800 1,673,600 1,673,600 0 9,790,500 9,204,700 7,531,100 0 447,662,900	0 802,400 0 836,800 0 836,800 0 1,673,600 0 5,439,200 0 9,790,500 9,204,700 0 0	0 802,400 0 836,800 1,673,600 1,673,600 0 0 5,439,200 0 9,790,500 0 0 0 4,937,100 0 9,790,500 0 0 0 0 0 0 4,937,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0,802,400 836,800 836,800 1,673,600 1,673,600 0,5,439,200 4,937,100 4,937,100 9,790,500 9,204,700 0 0	0 802,400 0 836,800 0 836,800 0 1,673,800 0 0 5,439,200 0 9,790,500 9,204,700 7,531,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 0 836,800 1,673,600 1,673,600 0 1,673,600 0 0 5,439,200 0 9,790,500 0 0 0 7,531,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 0 836,800 1,673,600 0 1,673,600 0 5,439,200 0 9,790,500 9,790,500 9,204,700 0 0 0 0 4,497,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 1,673,600 1,673,600 0 1,673,600 0 5,439,200 0 9,790,500 9,790,500 9,204,700 0 0 0 565,800	0 802,400 0 836,800 1,673,600 1,673,600 1,673,600 0 4,937,100 4,937,100 0 9,204,700 7,531,100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 802,400 836,800 1,673,600 1,673,600 1,673,600 0,4,937,100 4,937,100 0,9,790,500 9,204,700 9,204,700 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0
69 Total Revenue Bond Debt Service	25,164,000	23,029,500	22,672,000	21,911,700	22,079,000	22,807,400	22,177,800	23,772,800	21,436,300	23,122,800	21,944,600	21,186,300	26,524,900	29,371,600	34,214,300	30,135,300	28,449,700	36,097,800	45,194,000	50,820,500	50,394,900	49,740,200	49,632,900	49,522,100	47,662,900	47,662,900	47,662,900	48,248,700	49,922,300	51,261,200
70 GO Bond Debt Service	9,651,400	9,648,700	9,639,700	9,633,900	9,630,400	9,623,600	9,613,100	9,608,100	9,597,900	9,591,600	9,655,800	9,650,600	9,648,700	9,645,000	9,639,300	9,594,500	9,587,400	9,592,900	9,586,400	0	0	0	0	0	0	0	0	0	0	0
71 Total Operating Expenses 72 Annual Operating Balance	83,912,600 (5,251,200)		85,279,300 12.096,200	,,	,	87,398,200 23.895.300		91,240,700	90,415,000	93,668,700 19.191.500	94,180,700	95,106,000 18.601.100	102,184,600	7.656.000	1.382.800	3.937.500	111,639,300 4.023,700	121,809,800 3,284,400	133,522,100	1.313.800	1,739,300	154,226,200 2.406.900	157,337,100 2.559.400	2.640.500	162,137,200 4.515.400	165,695,300 4.348.500	4.214.200	3.401.500	179,478,100 3.131.200	3.196.500
73 Beginning Balance - Operating Funds	17,181,200	8,070,800	8,576,400	8,707,000	8,537,200	8,809,800	9,035,700	9,269,100	9,511,200	9,761,200	10,019,900	10,287,200	10,564,800	10,851,100	11,147,300	11,454,100	11,770,900	12,099,000	12,512,700	12,943,800	14,257,600	15,996,900	17,175,800	17,704,800	18,251,200	18,817,700	19,402,600	20,008,100	., . ,	21,296,800
 74 Funds from Annual Operating Balance 75 Transfer to Major Capital Improvement Financing 76 Ending Balance - Operating Funds 	(5,251,200) (3,859,200) 8,070,800			(20,621,000)			(23,240,000)			19,191,500 (18,932,800) 10,019,900	(18,770,200)	(18,323,500)			(1,076,000)	3,937,500 (3,620,700) 11,770,900	(3,695,600)	(2,870,700)		0	0	2,406,900 (1,228,000) 17,175,800	2,559,400 (2,030,400) 17,704,800		(3,948,900)	(3,763,600)	(3,608,700)	(2,775,000)	3,131,200 (2,469,000) 21,296,800	(2,511,100)
77 Minimum Operating Fund Balance [1]	8,070,800	8,576,400	8,707,000	8,537,200	8,809,800	9,035,700	9,269,100	9,511,200	9,761,200	10,019,900	10,287,200	10,564,800	10,851,100	11,147,300	11,454,100	11,770,900	12,099,000	12,512,700	12,943,800	15,458,700	16,665,500	17,175,800	17,704,800	18,251,200	18,817,700	19,402,600	20,008,100	20,634,600	21,296,800	21,982,200
Major Capital Improvement Financing 78 Beginning Balance - Capital Funds 79 Bond or Notel Issue 80 Issuance Costs 51 Debt Service Reserve 82 Transfer of Operating Funds 75 Total Available Capital Funds	3,859,200	3,859,200 10,000,000 (200,000) 8,826,300	18,327,500 0 0	10,000,000 (200,000) 20,621,000	28,099,700 0 0 25,329,500	7,880,600 10,000,000 (200,000) 23,669,400	0 0 23,240,000	20,598,900	19,825,600 0 0	20,000,000 (400,000) 18,932,800	0 0 18,770,200	32,590,400 0 0	65,000,000 (1,300,000) 11,625,500	39,069,200 59,000,000 (1,180,000) 7,359,800	59,000,000 (1,180,000) 1,076,000	0 0 3,620,700	0 0 3,695,600	117,000,000 (2,340,000) 2,870,700		90,000,000 (1,800,000)	5,131,800 0 0	5,131,800 0 0	6,359,800 0 0	8,390,200 0 0	10,484,300 0 0 3,948,900 14,433,200	14,433,200 0 0 3,763,600	0 0 3,608,700	(140,000) 2,775,000	5,249,800 20,000,000 (400,000) 2,469,000 27,318,800	(320,000)
83 Total Available Capital Funds 84 City CIP 85 Water Masterplan CIP 86 Ending Balance - Capital Funds 87 Target Fund Balance [2]	3,859,200 3,859,200 1,039,500	4,158,000 18,327,500	20,357,100 9,936,000	12,257,300 28,099,700		19,621,300 21,728,700				33,662,300 13,820,200	0 32,590,400	12,753,800 38,160,100	74,416,400 39,069,200	63,118,400	65,012,000 35,014,600	0 38,635,300		118,352,200 28,552,400	108,649,900 28,955,000		5,131,800	0	8,390,200 0 8,390,200 0	0 10,484,300 0	0 14,433,200 0 14,433,200 0	0 18,196,800 958,175	,,	,,	19,932,400	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Debt Service Coverage 88 Net Op Revenues Avail for Revenue Bond Debt Service 89 Annual Revenue Bond Debt Service 90 Total Debt Service Coverage Based on Net Op Revenues	42,615,300 25,164,000 1.69	57,581,000 23,029,500 2.50	60,150,000 22,672,000 2.65	68,472,900	74,244,800 22,079,000 3.36	73,390,900 22,807,400 3.22	72,462,000	71,559,700	70,569,500 21,436,300 3.29	69,530,700	68,410,200	67,368,300 21,186,300 3.18	66,172,700	64,921,100 29,371,600 2.21	63,652,300	62,251,400 30,135,300 2.07	60,819,200 28,449,700 2.14	68,364,500 36,097,800 1.89	76,523,200 45,194,000 1.69	72,911,100 50,820,500 1.43	73,452,400 50,394,900 1.46		74,193,800 49,632,900 1.49	74,519,200 49,522,100 1.50		75,108,800	75,360,100	75,526,700 48,248,700 1.57	77,422,300	79,332,400 51,261,200 1.55
91 Net Op Revenues Avail for Revenue Bond Debt Service 92 Annual Total Debt Service (Revenue and G.O.) 93 Total Debt Service Coverage Based on Net Op Revenues	42,615,300 34,815,400 1.22	57,581,000	60,150,000	68,472,900	74,244,800 31,709,400 2.34	73,390,900	72,462,000 31,790,900 2.28	71,559,700	70,569,500 31,034,200 2.27	69,530,700	68,410,200	67,368,300 30,836,900 2.18	66,172,700	64,921,100 39,016,600 1.66	63,652,300	62,251,400 39,729,800 1.57	60,819,200	68,364,500 45,690,700 1.50	76,523,200	72,911,100 50,820,500 1.43	73,452,400 50,394,900 1.46	73,800,600 49,740,200 1.48	74,193,800 49,632,900 1.49	74,519,200 49,522,100 1.50	74,904,100	75,108,800	75,360,100 47,662,900 1.58	75,526,700 48,248,700 1.57		79,332,400

[1] Equal to 60 days of O&M [2] Target Capital Fund Balance is equal to 25 percent of the following year CIP